

AN INVESTIGATION OF FORCED HYDROGEN EVOLUTION
AS A METHOD FOR PARTIAL CHARGING OF
LEAD-ACID STORAGE BATTERIES

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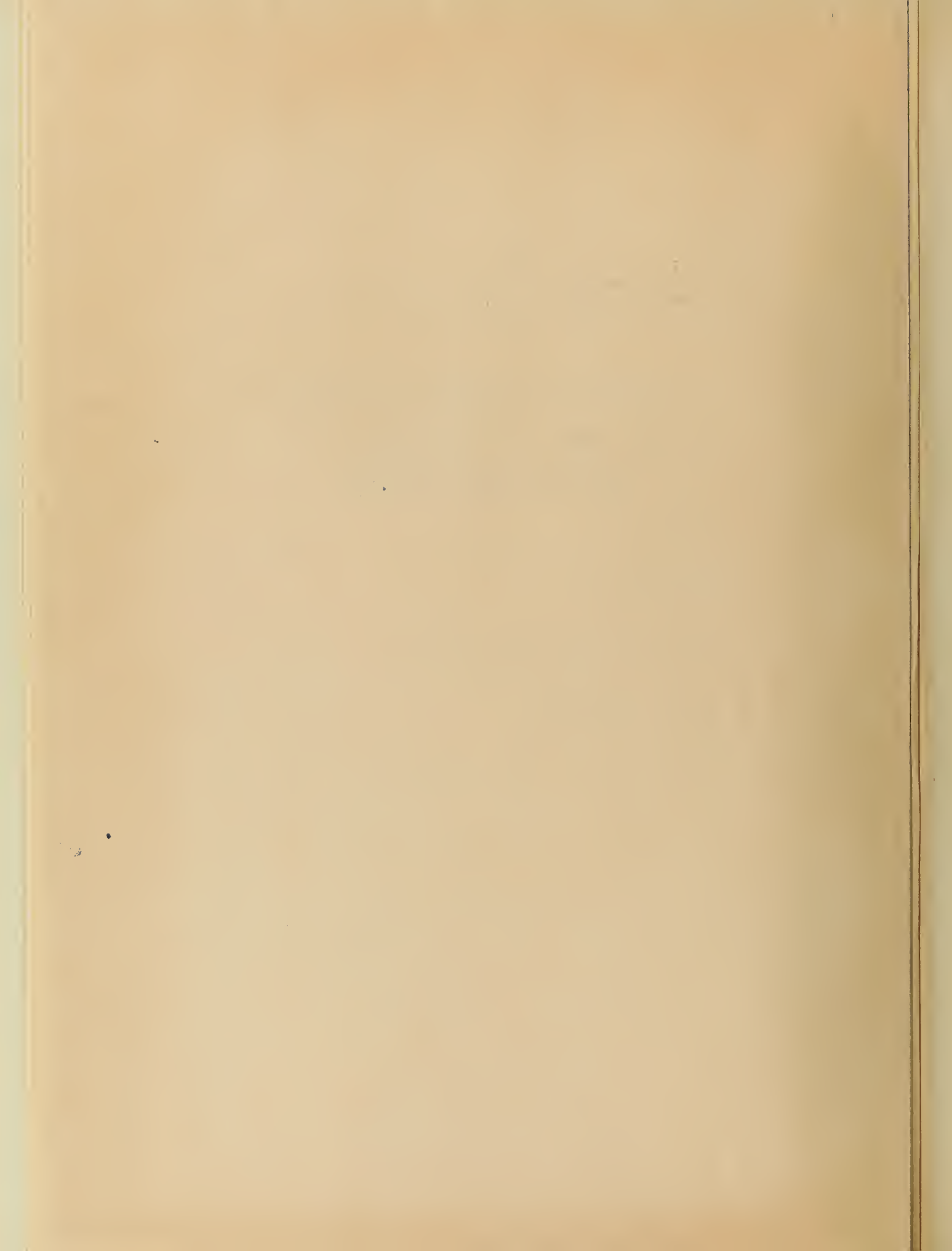
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AN INVESTIGATION OF FORCED HYDROGEN EVOLUTION
AS A METHOD FOR PARTIAL CHARGING OF
LEAD-ACID STORAGE BATTERIES

by

Clarence Couture Jr.

Lieutenant, United States Navy

Submitted in partial fulfillment
of the requirements
for the degree of
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PREFACE

In the various applications of storage batteries as a ready source of electrical energy, the extended time period that a lead-acid battery is out of service while being charged is in many ways a handicap to the user. In some instances the user may find it expeditious to return a battery to service after only a partial return to the fully charged condition.

The goal of this paper is to investigate a method of partial charging lead-acid storage batteries which has promise of being an improvement over those methods now commonly used. The writer wishes to thank Professor Allen E. Vivell of the U. S. Naval Postgraduate School for his assistance, encouragement, and cooperation in preparation of this paper.

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CHAPTER I

INTRODUCTION

1. The Electrolyte Mixture.

The specifications for charging lead-acid storage batteries are in the main directed towards achievement of best battery performance with regular use of what are commonly called normal charges and equalizing charges. One feature of these charges is that the gassing of the cells near the end of the charge breaks up local concentrations and stratification of heavier electrolyte in the lower portion of the cell. This heterogeneity of the electrolyte is known to contribute to poor battery performance. Mechanical mixing and/or recirculation of the electrolyte within the cells has been profitably utilized in the case of high capacity cells of the type used for submarine propulsion to produce a homogeneous electrolyte.

2. Objective.

The purpose of this thesis investigation is to determine whether or not battery performance can be improved when partial charging of the battery cells is necessary. There is no attempt here to show that partial charging of lead-acid cells is a commendable practice. Circumstances will at times dictate that a battery out of service for charging purposes be returned to service before a normal charge can be completed. If the probability of a partial charge can be anticipated, there may be better procedures for charging than an incomplete normal charge. One possible technique wherein the rate of charge is controlled in such

a manner to induce a moderate gassing condition as early in the charge as possible will be reported on herein. The gassing condition in the cells will of course stir the electrolyte thereby eliminating concentrations and stratification. This gassing condition ordinarily does not occur until the final stages of a normal charge and hence when a normal charge is prematurely secured as a partial charge.

3. Summary of Investigation Procedure.

The investigation was conducted using four standard stock, 6 volt, 3 cell, 50 ampere-hour capacity lead-acid batteries procured through regular naval supply channels. Other pertinent specifications are shown in BuShips Plan No. 9 S 4696-L included here as Appendix III. The basic procedure consisted of a discharge of several battery cells an equal number of ampere-minutes, after which a full set of readings of each cell's temperature and specific gravity were recorded. Immediately thereafter the cells were divided into two groups. One group was then charged at a rate to induce moderate gassing as would occur at the finishing rate of a normal charge. The other group was charged in accordance with the recommended normal charge procedure. Both groups were charged precisely the same number of ampere-minutes. Immediately after each charge a full set of readings was taken on each cell. At intervals varying from 24 hours to one week following the charge, a full set of readings was again taken. The results of observations made from each of the two groups were then compared for each cycle completed. The final evaluation was made from the composite evidence.

4. Historical Development of Lead-acid Cell.

In 1790 Alessandro Volta, an Italian physicist, discovered that if

electrodes of two chemically dissimilar conducting substances are immersed in an electrolyte which is capable of attacking one or both of the electrodes, an electromotive force is produced which accordingly sets up a flow of current when the external circuit between the two electrodes is closed. Such a combination of electrodes and electrolyte has since been called a "Voltaic Couple," after its discoverer.

In continuing his search in this direction, Volta also found that as long as the external circuit between the electrodes of the couple remained open, practically no chemical reaction between the electrolyte and the electrodes resulted; but, as has been stated, as soon as the external circuit was closed, chemical reaction was instantly brought about between the electrolyte and the electrodes, with the resultant flow of electrical current through the external circuit. This chemical reaction resolved itself into either dissolving the affirmative electrode in the electrolyte, or its combining with the electrolyte to form another substance.

Many years elapsed since volta gave his discovery to the world, and in which time many of the most prominent physicists of their respective times had diligently applied themselves to the task of evolving the theory and principles co-incident with the action of the voltaic couple, when in 1860 Gaston Plante, a French physicist, while engaged in certain related electrolytic research work in his laboratory, had set up a small cell in connection with his work; the electrodes of this cell consisted of plain rolled sheets of pure lead, while the electrolyte consisted of dilute sulphuric acid. Also, in series with the external circuit of this cell was connected a galvano-

meter.

During the course of his experiments and after he had been passing direct current through this small cell for some little time, Plante, while changing his connections, accidentally brought the terminals of the external circuit of this cell into contact with each other, whereupon he was surprised to observe the needle of the galvanometer swing to the opposite side of the scale, thus indicating that current was flowing through the external circuit in an opposite direction to that in which it had originally been flowing when passing current through the cell. Although it was noted that this secondary current lasted for a few seconds only, in following up his experiments Plante discovered that each time he repeated the operation, the duration of the secondary current increased, until after several such trials the secondary current became of quite appreciable magnitude. Furthermore, in continuing his research along this line, Plante discovered that if the direction of charging current through the cell were reversed each time, the resulting secondary current was increased in magnitude much more rapidly.

Upon further investigation Plante noted that whereas the surfaces of the lead plates were originally bright before placing them in the sulphuric acid, they immediately became coated with a white filmy substance when placed in the acid. This feature of the experiment is accounted for by the fact that sulphuric acid has a great affinity for metals, and the white filmy substance on the surfaces of the lead plates was the lead-sulphate formed as a result of the action of the sulphuric acid on the lead.

Plante also noted that when current had been passing through the cell for some little time the white coating on the surface of the positive plate became dark brown in color, and that on the negative plate a light gray. Subsequent chemical analysis proved the dark brown substance on the surface of the positive plate to be lead-peroxide, or a sort of lead rust, and the light gray substance of the negative plate, sponge lead, or metallic lead in a spongy state.

Also, upon discharging the cell, Plante noted that these substances gradually changed in color until they again became white. Further examination revealed the fact that at the end of the discharge the surfaces of both plates had again been converted into lead-sulphate. Also, each time this experiment was repeated, the coatings on the surfaces of the plates became thicker, which accounts for the increase in capacity of the cell noted during the course of his experiments. This type of plate has since been called a "Plante plate," after its discoverer.

Thus it is seen that Plante, in passing a direct current through this small cell containing the pure lead electrodes and dilute sulphuric acid, had unconsciously converted it into a formidable voltaic couple, the active components of which were lead-peroxide, sponge lead, and dilute sulphuric acid. Moreover, he had produced a voltaic couple, all elements of which were capable of restoration to their original state, after exhaustion, by passing current through the cell in the opposite direction, and it is as a result of this discovery and the principles involved that the modern storage battery has been developed.

Although Plante had discovered a reversible voltaic couple, months of charge, discharge and reversal were necessary with his process in

order to form layers of lead-perioxide and sponge lead of sufficient thickness to produce a battery having any material capacity. Therefore it remained for the next important step in the development of the storage battery to be taken in the direction of a reduction in the time element necessary to complete this "forming process."

This highly important and advanced step in the development of the storage battery was achieved in 1880 when a Frenchman, Camille Faure, in France, and an American, Charles F. Brush, in America, practically simultaneously discovered a process by which a thick coating of lead-oxide, when mixed with sulphuric acid and worked up into a paste of putty-like consistency, could be applied to a skeleton framework or "grid," thus forming a plate, and that by placing these plates in dilute sulphuric acid and passing a single low rate charge through them, the lead-oxide on the respective positive and negative plates was converted into highly porous lead-peroxide and sponge lead. These plates have since been called "Faure" or "pasted plates."

Since their discovery, these paste plates have undergone successive stages of development in the way of improved methods of combining and mixing the paste, as well as improvement in the design and construction of the grids, separators and other component parts.

Although the development of the pasted type plate had insured the ultimate success of the storage battery as an efficient energy producing agent, the development of this art was not confined entirely to the paste type plates, as physicists, electrochemists and inventors were constantly engaged in trying to develop an improved method for the "forming process" of Plante plates. This field of endeavor was not

without favorable results, as is indicated by the fact that the modern "forming" methods employed in the manufacture of Plante plates are capable of producing these plates about as quickly and as cheaply as those employed in producing Faure or "paste plates."

The development of both of the above types of plates has proceeded hand in hand, each having contributed its share to the successes achieved in this very important branch of electrical engineering. Each type of plate has its own particular field of efficient service, and in some instances these services require that both types be installed in the same cell. In this regard, it may be said that, generally speaking, paste plates are used where maximum capacity per unit of weight is required and where life is not a governing factor, whereas, Plante plates are used for services in which weight is not a material factor and the desirability for long life is paramount.

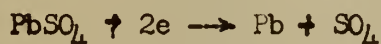
CHAPTER II

CELL BEHAVIOR WHEN CHARGING AND DISCHARGING

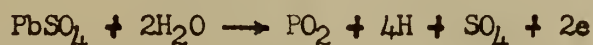
1. Charging.

The reactions that occur at the negative and positive plates in lead-acid storage batteries during charge may be formulated as follows:

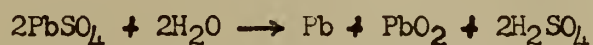
a) Negative plate:



b) Positive plate:



c) Over-all cell reaction during charge:

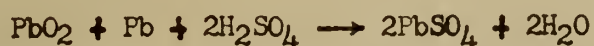


In the above formulas e symbolizes electron and the other symbols have their usual chemical formula significance. One measure of the efficiency of the charging process is the amount sulphuric acid produced in (c) above. This criteria will be used as the main basis for evaluating the forced gassing charging technique.

2. Discharging.

In discharging the current produced by a lead-acid storage cell when an electrically conductive circuit is established across its terminals is a result of chemical reaction of dilute sulphuric acid on the active materials, consisting of lead peroxide in the positive plate and sponge lead in the negative plate. In accordance with the generally accepted double sulphate theory, the reactions during a discharge result in the formation of lead sulphate at both the positive and negative plates and the acid consumed in the process is replaced by a

corresponding amount of water. This can be expressed in a chemical equation as follows:



As the discharge progresses the water formed diffuses into the electrolyte to bring about a reduction in the specific gravity. This reduced specific gravity is a measure of the state of discharge of a battery.

It is to be noted that the phrase, "generally accepted double sulphate theory," used above and in use in the current battery literature signifies that, as from the first discoveries of Plante, battery development has not proceeded as an exactly formulated mathematical science.

CHAPTER III

LOG OF EXPERIMENTAL PROCEDURE AND DATA

1. October 1, 1954 to February 6, 1955.

The preliminary events began with the original idea to do thesis work in connection with lead-acid battery charging technique early in October 1954. The plan was further developed and outlined during the remaining weeks of October, and approval to proceed with the project was received from the Electrical Engineering Department on November 5, 1954. Soon thereafter, following consultation with Prof. A. E. Vivell as to size of batteries to be used and other details of the project, it was decided that the six volt, 50 ampere-hour size batteries available in Navy standard stock were best for the service required.

The batteries were placed on order in the regular Naval Supply Channels and arrived in Monterey dry of electrolyte about 15 January 1955. After a few days thought and investigation in connection with preparing the batteries for service, it was decided that the job could be best accomplished by the battery shop at Fort Ord, California. Thus the batteries were finally received fully charged and ready for service 1 February 1955. Installation and flexible circuit connection were completed 4 February 1955.

2. Monday 7 February 1955

Time 0920 - Commenced 50 ampere rate discharge of all batteries.

Time 0925 - Reduced rate to 48 amperes.

Time 0937 - Reduced rate to 46 amperes.

Time 0942 - Secured discharge; open circuit voltage is 23.0 volts

for the 12 battery cells in series.

Time 1015 - Observed and recorded ampere-hour meter reading as 18.5.

Time 1018 - Commenced charging batteries A, B, and C at 27 ampere rate; cell C1 commenced gassing immediately.

Time 1047 - Cell A1 commenced gassing.

Time 1048 - Reduced charging rate to 17 amperes; Cell A1 and C1 stop gassing. Ampere-hour meter reading is now 21.5.

Time 1055 - Cells A1 and C1 commence gassing again.

Time 1059 - Secured charge and removed cell caps for purpose of direct observation of gassing in cells.

Time 1100 - Resumed charging at 15 ampere rate and observed moderate gassing in cell A1.

Time 1106 - Increased charging rate to 20 amperes and observed gassing conditions in cell C1; cell B2 now gassing.

Time 1108 - Cell B1 commences to gas.

Time 1111 - Secured charge and observed specific gravities and temperatures as follows:

a) Cell A1....1195 and 84

b) Cell A2....1180 and 82

c) Cell B2....1175 and 81

Time 1132 - Commenced charging battery D only at 30 ampere rate.

Time 1135 - Changed charging rate to 20 amperes.

Time 1203 - Changed charging rate to 10 amperes.

Time 1225 - Changed charging rate to 5.0 amperes.

Time 1317 - Secured charge; no gassing occurred during this charge.

3. Tuesday 8 February 1955

Time 1115 - Commenced slow charge of battery D at 6.0 ampere rate.

Time 1124 - Commenced charging batteries A, B, and C at 17 ampere rate. Cells A1, B2, B3, and C1 commenced gassing immediately. Intend to continue this rate until all cells are gassing provided none become too violent. Ampere-hour meter reading at start of this charge is 25.2.

Time 1125 - Changed charging rate to 5.5 amperes for battery D.

Time 1150 - Changed charging rate to 5.0 amperes for battery D.

Time 1209 - Cell C3 commenced gassing.

Time 1229 - Changed charging rate to batteries A, B, and C to 20 amperes.

Time 1255 - Secured charge to batteries A, B, and C to inspect cell A2 and other cells now gassing. Light haze and moderate bubbling of electrolyte observed in cell A2. Temperature of this cell is 94 degrees.

Time 1305 - Resumed charge to batteries A, B, and C at 15 ampere rate.

Time 1307 - Changed charging rate to 10 amperes to batteries A, B, and C; all cells were gassing at 15 ampere rate. Cells A1, B2, B3, C1, C2, C3 still gassing.

Time 1330 - Change charging rate to 5.0 amperes to batteries A, B, and C.

Time 1455 - Changed charging rate to battery D to 4.0 amperes.

Time 1513 - Secured charges to all batteries.

4. Wednesday 9 February 1955

Time 0900 - Commenced charging all batteries at 4.0 amperes for start of equalizing charge.

Time 0905 - All battery cells gassing at 10 ampere rate; reduce charging rate to 4.0 amperes.

Time 0907 - Several cells from all four batteries are now gassing at the 4.0 ampere rate.

Time 0930 - Observed and recorded specific gravity and temperature of pilot cells.

Time 1015 - Same as above entry.

Time 1100 - Same as above entry.

Time 1200 - Same as above entry.

Time 1300 - Same as above entry.

Time 1350 - Same as above entry.

Time 1430 - Same as above entry.

Time 1500 - Same as above entry.

Time 1530 - Same as above entry.

Time 1531 - Equalizing charge completed and secured; observed and recorded specific gravity and temperature of pilot cells.

5. Thursday 10 February 1955

Time 1045 - Made all preparations for discharging batteries.

Time 1057 - Commenced 41 ampere rate discharge on battery D.

Time 1102 - Discharge rate dropped to 40.5 amperes.

Time 1107 - Discharge rate dropped to 40.0 amperes.

Time 1117 - Secured discharging battery D; observed specific gravity of pilot cell as 1.210 and temperature as 78 degrees.

Time 1120 - Made all preparations for charging batteries.

Time 1125 - Commenced charging battery D at 10 ampere rate.

Time 1230 - Observed that charging rate has dropped to 7.0 amperes



due to malfunction of charger; increased rate to 9.5 amperes.

Time 1243 - Changed charging rate to 8.0 amperes as charger appears to be overheating.

Time 1250 - Interrupted charge to add ampere-hour meter to charging circuit.

Time 1255 - Resumed charging at 8.0 ampere; ampere-hour meter reading 43.0.

Time 1310 - Commenced 20 minute discharge of batteries A, B, and C at 40.5 ampere rate.

Time 1320 - Discharge rate has dropped to 40.0 amperes.

Time 1325 - Discharge rate has dropped to 39.5 amperes.

Time 1330 - Secured discharging batteries A, B, and C.

Time 1335 - Made all preparations for charging batteries A, B, and C.

Time 1346 - Commenced charging batteries A, B, and C at 40 ampere rate.

Time 1349 - Changed charging rate to 30 amperes since six of nine cells in batteries were gassing.

Time 1351 - Changed charging rate to 35 amperes.

Time 1358 - Changed charging rate to 30 amperes to reduce gassing rate of cells to moderate amount.

Time 1400 - Changed charging rate to 25 amperes to reduce gassing.

Time 1406 - Changed charging rate to 20 amperes to reduce gassing.

Time 1412 - Changed rate to 4.0 amperes to battery D since its cells were all gassing freely.

Time 1415 - Changed charging rate to 15 amperes to batteries A, B, and C to reduce gassing.

Time 1420 - Change charging rate to 4.0 amperes to reduce gassing.

Time 1440 - Observed specific gravity of cell B1 to be 1227; several cells in batteries A, B, and C now gassing at the 4.0 ampere rate; observed the specific gravity of cell B1 to be 1237, no gravity is available from cell B2 due to insufficient electrolyte above plates to lift hydrometer float.

Time 1445 - Secured charging all batteries with summary of events as follows:

a) Batteries A, B, and C

Discharged for....802.5 ampere-minutes.

Charged for....918.5 ampere-minutes.

b) Battery D

Discharged for....808 ampere-minutes.

Charged for....1433 ampere-minutes.

Note: Battery D greatly overcharged due to insufficient reading to determine state of charge. Addition of ampere-hour meter to battery D charging circuit intended to prevent repetition. No basis is available for comparison of today's charging due to unintentional overcharge of battery D.

6. Friday 11 February 1955

Time 0835 - Made all preparations for discharging Group Two battery. The temperature is 56 degrees and the corrected pilot cell gravity is 1232; watered battery. Note that hereafter battery D will be referred to as Group Two battery. The designation Group Two will be used for the batteries being charged with a normal charging procedure and it is intended to change the batteries A, B, C, and D between groups one and two

as time permits. Group One will include the batteries charged at a forced gassing rate.

Time 0855 - Commenced 40 ampere rate discharge of Group Two battery.

Time 0919 - Secured discharging Group Two battery with total discharge of 1000 ampere-minutes.

Time 0920 - Made all preparations for charging Group Two battery.

Time 0923 - Commenced charging Group Two battery at 8.0 ampere rate.

Time 0953 Changed charging rate to 7.0 amperes due to limitations of charger.

Time 1035 - Changed charging rate to 8.0 amperes and made all preparations for discharging Group One battery. The temperature of Group One is 60 degrees and the specific gravity is 1.232.

Time 1045 - Commenced discharge of Group One battery at 40 ampere rate.

Time 1111 - Changed charging rate to 9.5 amperes to Group Two in order to complete charge prior to next class.

Time 1113 - Changed charging rate to 9.0 amperes to Group Two battery. This is now the maximum output of Group Two's charger.

Time 1117 - Secured discharge of Group One battery with total output at 1120 ampere minutes.

Time 1120 - Changed Group Two battery charging rate to 8.7 amperes.

Time 1123 - Changed Group Two charging rate to 4.0 amperes as cell D1 commences gassing.

Time 1125 - Secured charge to Group Two battery.

Time 1235 - Made all preparations for charging Group One battery including watering of cells.

Time 1245 - Commenced charging Group One battery at 40 ampere rate.

Time 1246.5 - Changed charging rate to 30 amperes to reduce gassing rate of cells.

Time 1253 - Changed Group One charging rate to 35 amperes to reduce gassing rate of cells.

Time 1256 - Changed Group One charging rate to 30 amperes to reduce gassing rate of cells.

Time 1259 - Changed Group One charging rate to 25 amperes to reduce gassing rate of cells.

Time 1304 - Changed charging rate to Group One to 20 amperes to reduce gassing rate of cells.

Time 1312 - Changed charging rate to Group One to 15 amperes to reduce gassing rate of cells.

Time 1322 - Changed Group One charging rate to 10 amperes to reduce gassing rate of cells.

Time 1329 - Resumed charging Group Two battery at 4.0 ampere rate.

Time 1332 - Changed Group One charging rate to 4.0 amperes to reduce gassing of cells.

Time 1342 - Secured charging Group Two battery with total input this charge at 1000 ampere-minutes.

Time 1353 - Secured charging Group One battery with total input this charge at 1136 ampere-minutes.

Time 1400 - Observed corrected specific gravities of pilot cells to be as follows:

Cell D1....1180

D2....1186



D3....1177

A1....1184

B1....1204

C1....1189

Note: The above data is favorable to the forced gassing rate charge.

However, this indication may be modified when full consideration of the results of watering cells is taken into account. Such accounting can not be made until the electrolyte has had time to equalize its concentration over a period of the next several hours.

7. Tuesday 15 February 1955

Time 1100 - Decided after consideration of preceding results that better comparison data can be obtained using a reference gravity rather than the more general specifications for the fully charged condition of batteries. Hence, based on last equalizing charge date, a corrected specific gravity of 1230 will be considered fully charged condition of all batteries. The standard height for electrolyte reference level has been noted and recorded.

Time 1215 - Made all preparations for charging both battery groups to fully charged condition.

Time 1230 - Commenced charging both battery groups.

Time 1600 - Secured charging both batteries with both less than fully charged.

Time 1610 - Observed and recorded specific gravity and temperature of all pilot cells.

8. Thursday 17 February 1955

Time 1100 - Corrected gravity of Group One battery now 1213;

corrected gravity of Group Two battery now 1214. Group One rise in gravity due to chemical equalization is one point since completion of last charge. Similarly Group Two rise is two points.

Time 1127 - Commenced 40 ampere rate discharge of Group Two battery.

Time 1144 - Secured discharged after 680 ampere-minute discharge.

Time 1159 - Commenced 40 ampere rate discharge of Group One battery.

Time 1216 - Secured discharge of Group One battery after 680 ampere-minute discharge.

Time 1227 - Commenced normal charge of both Group One and Group Two batteries simultaneously on one charging circuit to return batteries to standard gravity charge condition.

9. Wednesday 16 February 1955

Time 0900 - Observed and recorded gravities of both battery groups. Group One corrected reading is 1232; Group Two corrected reading is 1238. Hence 1232 is designated standard corrected gravity for Group One. Resumed charge of Group Two battery.

Time 0952 - Commenced 40 ampere rate discharge of Group One battery.

Time 1000 - Secured charging Group Two battery; corrected gravity reading is 1231. Hence 1231 is designated standard corrected gravity for Group Two battery.

Time 1012 - Completed 20 minute discharge of Group One battery at 40 ampere rate. Total discharge 800 ampere-minutes.

Time 1020 - Commenced 40 ampere rate discharge of Group Two battery. 800 ampere-minutes discharged.

Time 1041 - Commenced charging Group Two battery at 8.0 ampere rate.

Time 1118 - Group Two charging rate noted to have dropped to 6.5

amperes. increased rate to 8.0 amperes. 290 ampere-minute running total input this charge.

Time 1127 - Commenced charging Group One battery at .30 ampere rate to produce moderate gassing condition.

Time 1149 - Reduced Group One charging rate to 25 amperes. 360 ampere-minutes running total input this charge.

Time 1154 - Reduced Group One charging rate to 20 amperes. 485 ampere-minutes running total input this charge.

Time 1159 - Reduced Group One charging rate to 15 amperes. 585 ampere-minutes running total ampere minutes input this charge.

Time 1207 - Reduced Group One charging rate to 10 amperes. 705 ampere-minutes running total input this charge.

Time 1213 - Reduced Group One charging rate to 4.0 amperes. 765 ampere-minutes running total input this charge.

Time 1222 - Completed charging both Group One and Group Two batteries. 800 ampere-minutes each is total input to batteries.

Time 1228 - Observed and recorded average specific gravities of pilot cells as follows:

a) Group One.....1212

b) Group Two.....1212

10. Saturday 19 February 1955

Time 1300 - Observed and recorded corrected gravities of each cell in order to place analysis on a per cell basis.

Time 1330 - Made all preparations for discharging batteries.

Time 1345 - Commenced 40 ampere rate discharge of both batteries simultaneously.

Time 1405 - Secured discharge; observed and recorded specific gravities and temperature of each cell. Total output is 800 ampere-minutes for this discharge.

Time 1425 - Made all preparations for charging batteries.

Time 1432 - Commenced charging Group Two battery at 8.0 ampere rate.

Time 1448 - Commenced charging Group One battery at 30 ampere rate; no gassing occurs so after one minute increased charge to 40 ampere rate. After one minute several cells gassing so reduced rate to 35 amperes. 70 ampere-minutes is running total input to Group One battery this charge.

Time 1501 - Reduced rate to Group One to 30 amperes with several cells gassing 455 ampere-minutes running total input this charge.

Time 1505 - Reduced rate Group One to 25 ampere minutes. 575 ampere-minutes is running total input this charge.

Time 1507 - Reduced rate to Group One to 20 amperes. 625 ampere-minutes is running total input this charge.

Time 1512.4 - Reduced Group One charging rate to 15 amperes. 733 ampere-minutes is running total input this charge.

Time 1517 - Secured charge to Group One battery. 800 ampere minutes is total input this charge.

Time 1612 - Secured charge to Group Two battery. 800 ampere minutes is total input this charge.

Time 1615 - Observed and recorded specific gravity and temperature of Group Two battery cells.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>B3</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>D1</u>	<u>D2</u>	<u>D3</u>
-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------

CHARGED

Reading:

1235	1224	1235	1222	1219	1217	1231	1225	1224	1200	1223	1230
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

74	74	74	73	74	74	74	74	74	74	74	74
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1233	1222	1233	1220	1217	1215	1229	1223	1222	1198	1221	1228
------	------	------	------	------	------	------	------	------	------	------	------

DISCHARGED

Reading:

1207	1205	1207	1203	1200	1192	1206	1200	1196	1180	1192	1204
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

77	77	78	77	78	77	78	77	77	78	78	77
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1206	1204	1206	1202	1199	1191	1205	1199	1195	1179	1191	1203
------	------	------	------	------	------	------	------	------	------	------	------

RECHARGED

Reading:

1225	1208	1222	1212	1207	1207	1214	1216	1217	1188	1210	1214
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

84	84	83	84	84	84	88	84	83	80	80	80
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1226	1209	1223	1213	1218	1208	1216	1217	1218	1188	1210	1214
------	------	------	------	------	------	------	------	------	------	------	------

PERCENT RECOVERY

Immediately after charge:

74.1	27.8	63.0	61.1	50.0	70.8	45.9	75.0	85.2	47.4	63.3	44.0
------	------	------	------	------	------	------	------	------	------	------	------

48 hours after charge:

88.9	11.1	66.7	88.9	88.9	91.7	58.3	87.4	96.4	73.7	73.5	68.0
------	------	------	------	------	------	------	------	------	------	------	------

11. Monday 21 February 1955

Time 0900 - Observed and recorded gravities of both battery groups.

Time 0915 - Made all preparations for discharging batteries.

Time 0939 - Commenced 40 ampere rate discharge of both batteries simultaneously.

Time 0959 - Completed battery discharge 800 ampere-minutes total output this discharge.

Time 1000 - Made all preparations for charging batteries.

Time 1003 - Commenced charging Group Two battery at 10 ampere rate.

Time 1036 - Interrupted charge on Group Two battery.

Time 1049 - Resumed charge on Group Two battery.

Time 1117 - Reduced rate of charge to Group Two battery to 9.0 amperes; 610 ampere-minutes is running total this charge.

Time 1132 - Changed charging rate to 8.0 amperes to Group Two battery; 745 ampere-minutes is running total this charge.

Time 1135 - Completed 800 ampere-minute charge of Group One battery as follows: one minute at 40 amperes, seven minutes at 35 amperes, six minutes at 30 amperes, five minutes at 25 amperes, 8 minutes at 20 amperes; 800 ampere-minutes is total input this charge.

Time 1139 - Completed charging Group Two battery. 800 ampere-minutes is total input this charge.

Time 1140 - Observed and recorded specific gravity and temperature of all cells.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>B3</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>D1</u>	<u>D2</u>	<u>D3</u>
-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------

CHARGED

Reading:

1235	1210	1230	1222	1219	1217	1223	1224	1205	1197	1217	1224
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

66	67	67	67	67	67	67	67	67	67	67	67
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1230	1206	1224	1218	1215	1213	1219	1220	1221	1193	1213	1220
------	------	------	------	------	------	------	------	------	------	------	------

DISCHARGED

Reading:

1203	1190	1200	1185	1186	1187	1197	1191	1190	1177	1186	1198
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

70	70	71	70	70	70	71	70	70	70	70	70
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1200	1187	1196	1182	1183	1184	1194	1188	1187	1174	1183	1195
------	------	------	------	------	------	------	------	------	------	------	------

RECHARGED

Reading:

1230	1221	1226	1214	1210	1211	1221	1218	1216	1186	1209	1211
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

78	79	78	80	79	78	81	80	78	73	74	74
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1229	1221	1225	1214	1210	1210	1221	1218	1215	1184	1207	1209
------	------	------	------	------	------	------	------	------	------	------	------

PERCENT RECOVERY

Immediately After Charge:

96.8	200.0	96.6	88.9	81.9	89.6	104.0	93.9	82.3	52.6	80.0	56.0
------	-------	------	------	------	------	-------	------	------	------	------	------

48 Hours After Charge:

100.0	136.8	114.0	89.0	87.5	89.6	116.0	100.0	91.2	100.0	93.2	80.0
-------	-------	-------	------	------	------	-------	-------	------	-------	------	------



12. Wednesday 23 February 1955

Time 0900 - Observed and recorded gravity and temperature of each cell; made preparations for discharge.

Time 0936 - Commenced 40 ampere rate discharge of both batteries simultaneously.

Time 0956 - Secured discharge; observed and recorded gravity and temperature of each cell.

Time 1036 - Commenced charging Group Two battery at 10 ampere rate.

Time 1123 - Interrupted charge to Group Two battery due to casualty at start Group One charge. Upon throwing the switch closed in starting Group One charge, the cell connector between battery B and C commenced arcing at B's terminal post. The connector broke from its clamp at the C terminal and the arcing destroyed a portion of the B battery terminal. This casualty resulted from accidental short circuiting in current limiting resistor connection.

Time 1130 - Repaired connector between batteries B and C and secured for day.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>B3</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>D1</u>	<u>D2</u>	<u>D3</u>
-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------

CHARGED

Reading:

1235	1217	1232	1218	1215	1214	1227	1224	1222	1197	1215	1219
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

66	67	67	67	68	67	68	68	67	68	68	68
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1230	1213	1228	1214	1211	1210	1223	1220	1218	1193	1211	1215
------	------	------	------	------	------	------	------	------	------	------	------

DISCHARGED

Reading:

1201	1191	1202	1190	1187	1185	1198	1190	1187	1175	1186	1195
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

70	70	72	70	70	70	73	71	70	70	71	71
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1198	1188	1199	1187	1184	1182	1196	1187	1184	1172	1183	1192
------	------	------	------	------	------	------	------	------	------	------	------

PERCENT RECOVERY

Immediately After Charge: No data.

48 Hours After Charge: No data.

Controlled charge interrupted by connector casualty. Next charge to be normal charge to standard gravity.

13. Thursday 24 February 1955

Time 0100 - Commenced replacement of clamp type interconnectors between batteries in favor of a plug, lug, and jackbox arrangement which provide same flexibility and more secure connection.

Time 0130 - Commenced normal charge of all batteries to return them to standard reference gravity.

Time 1600 - Secured charging as all batteries are ready for finishing rate of four amperes when charge is resumed.

14. Friday 25 February 1955

Time 0845 - Resumed normal charge of both battery groups.

Time 1400 - Secured charge and made preparations for test discharge.

Time 1430 - Commenced test discharge at 40 ampere rate.

Time 1450 - Discharge completed. 820 ampere-minutes taken from both batteries.

Time 1503 - Commenced charging Group Two battery at 10 ampere rate.

Time 1523 - Commenced charging Group One battery at 40 ampere rate.

Time 1533 - Changed rate Group One to 35 amperes. 420 ampere-minutes is running total input to Group One this charge.

Time 1536 - Changed to 30 ampere rate on Group One charge. 525 ampere-minutes is running total input.

Time 1548 - Charging rate reduced in accordance with gassing rate to 10 ampere rate this time. 732.5 ampere-minutes is running total input.

Time 1558 - Secured Group One charge with 820 ampere minute input this charge.

Time 1625 - Secured charging Group two battery with 820 ampere-minute input this charge.

Time 1630 - Observed and recorded gravity and temperature of
each cell.

NOTE: SEE NEXT PAGE FOR DATA FOR THIS DATE.

CELL:

<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>B3</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>D1</u>	<u>D2</u>	<u>D3</u>
-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------

CHARGED

Reading:

1238	1225	1231	1227	1224	1225	1238	1232	1231	1217	1226	1238
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

80	80	80	80	80	80	80	80	80	79	79	78
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1238	1225	1231	1227	1224	1225	1238	1232	1231	1217	1226	1237
------	------	------	------	------	------	------	------	------	------	------	------

DISCHARGED

Reading:

1205	1200	1203	1199	1196	1198	1210	1201	1201	1190	1201	1216
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

78	79	78	80	80	80	78	80	78	80	80	78
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1204	1200	1202	1199	1196	1198	1209	1201	1200	1190	1201	1215
------	------	------	------	------	------	------	------	------	------	------	------

RECHARGED

Reading:

1219	1207	1211	1212	1206	1204	1218	1211	1211	1195	1211	1220
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

80	82	82	81	83	81	82	82	81	78	80	78
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1219	1208	1212	1212	1207	1204	1219	1212	1211	1194	1211	1219
------	------	------	------	------	------	------	------	------	------	------	------

PERCENT RECOVERY

Immediately After Charge:

44.1	32.0	34.5	46.5	39.3	22.2	34.5	36.7	36.7	14.8	40.0	23.5
------	------	------	------	------	------	------	------	------	------	------	------

24 Hours After Charge:

58.8	52.0	51.8	39.3	39.3	29.6	38.0	50.0	46.7	25.9	40.0	29.4
------	------	------	------	------	------	------	------	------	------	------	------

15. Saturday 26 February 1955

Time 1330 - Observed and recorded specific gravities and temperature of each cell.

Time 1345 - made preparations for discharge of both batteries.

Time 1355 - Commenced discharge of both batteries simultaneously at the 40 ampere rate.

Time 1400 - Calculated efficiency of last charge.

Time 1415 - Secured discharge of both batteries. 800 ampere-minutes out this discharge.

Time 1416 - Observed and recorded specific gravities and temperature of each cell.

Time 1421 - Commenced charging Group Two battery at 10 ampere rate.

Time 1425 - Made preparations for charging Group One battery.

Time 1444 - Commenced charging Group One battery at rates to produce moderate gassing of cells starting with 40 amperes for three minutes.

Time 1510 - The following rates were used in charging Group One:

- a) 40 amperes for three minutes.
- b) 35 amperes for eight minutes.
- c) 30 amperes for 2.0 minutes.
- d) 25 amperes for 3.0 minutes.
- e) 20 amperes for 5.0 minutes.
- f) 15 amperes for 5.0 minutes.
- g) 10 amperes for 5.0 minutes.
- h) 4.0 amperes for 7.5 minutes.

Time 1541 - Secured charging Group Two battery with 800 ampere-minutes in.

Time 1545 - Observed and recorded gravities and temperature of each cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.



CELL:

<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>B3</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>D1</u>	<u>D2</u>	<u>D3</u>
-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------

CHARGED

Reading:

1225	1219	1223	1216	1213	1212	1226	1222	1220	1203	1217	1226
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

61	62	62	63	63	63	62	63	62	62	62	62
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1224	1213	1217	1210	1207	1206	1220	1216	1214	1197	1211	1220
------	------	------	------	------	------	------	------	------	------	------	------

DISCHARGED

Reading:

1207	1198	1203	1200	1192	1194	1206	1198	1199	1187	1203	1212
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

64	64	65	65	65	65	65	65	65	65	65	65
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1202	1193	1198	1195	1187	1189	1201	1193	1194	1182	1198	1207
------	------	------	------	------	------	------	------	------	------	------	------

RECHARGED

Reading:

1213	1201	1206	1210	1199	1202	1214	1205	1209	1198	1211	1220
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

68	69	69	69	70	69	69	70	68	67	66	66
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1209	1197	1202	1206	1196	1198	1210	1202	1205	1194	1206	1215
------	------	------	------	------	------	------	------	------	------	------	------

PERCENT RECOVERY

Immediately After Charge:

31.8	20.0	21.0	73.4	45.0	53.0	47.4	33.3	55.0	80.0	61.5	61.5
------	------	------	------	------	------	------	------	------	------	------	------

48 Hours After Charge:

68.2	65.0	57.9	106.5	75.0	76.5	79.0	63.0	80.0	93.4	107.5	107.5
------	------	------	-------	------	------	------	------	------	------	-------	-------

16. Monday 28 February 1955

Time 0900 - Observed and recorded gravities and temperatures of all cells.

Time 0915 - Cleaned cell tops and made preparations to discharge batteries.

Time 1000 - Commenced discharge of both batteries simultaneously at 40 ampere rate. Secured discharge after 800 ampere minutes taken out.

Time 1025 - Observed and recorded gravities and temperature of each cell.

Time 1032 - Commenced charging Group Two battery at 10 ampere rate.

Time 1055 - Commenced charging Group One battery at maximum rates to produce moderate gassing as follows:

- a) Eight minutes at 40 amperes.
- b) Three minutes at 35 amperes.
- c) Two and one-half minutes at 30 amperes.
- d) Three minutes at 25 amperes.
- e) Three minutes at 20 amperes.
- f) Three minutes at 15 amperes.
- g) Eight minutes at 10 amperes.
- h) Ten minutes at 4 amperes.

Time 1138 - Changed Group Two charging rate to nine amperes to keep within limitations of charger. 660 ampere-minutes is running total input this charge.

Time 1154 - Secured charging group Two battery with 800 ampere-minute input this charge. Cells in this battery did not gas during charge.

Time 1215 - Observed and recorded gravity of each cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>B3</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>D1</u>	<u>D2</u>	<u>D3</u>
-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------

CHARGED

Reading:

1222	1211	1214	1216	1207	1207	1221	1215	1215	1201	1217	1226
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

64	64	64	64	64	64	64	64	64	64	64	64
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1217	1206	1209	1211	1202	1202	1216	1210	1210	1196	1212	1221
------	------	------	------	------	------	------	------	------	------	------	------

DISCHARGED

Reading:

1203	1191	1196	1195	1189	1187	1203	1196	1194	1182	1192	1205
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

66	66	66	66	66	66	66	66	66	65	66	66
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1198	1186	1191	1190	1184	1182	1198	1191	1189	1177	1187	1200
------	------	------	------	------	------	------	------	------	------	------	------

RECHARGED

Reading:

1208	1195	1203	1206	1197	1196	1207	1202	1203	1191	1208	1212
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

74	74	74	74	73	73	73	74	73	71	71	71
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1206	1193	1201	1204	1195	1194	1205	1200	1201	1189	1205	1209
------	------	------	------	------	------	------	------	------	------	------	------

PERCENT RECOVERY

Immediately After Charge:

42.1	35.0	55.5	66.6	61.2	60.0	38.9	47.3	57.1	57.9	72.0	42.8
------	------	------	------	------	------	------	------	------	------	------	------

24 Hours After Charge:

52.6	60.0	88.9	85.7	94.4	95.0	61.1	73.6	76.3	84.2	84.0	71.4
------	------	------	------	------	------	------	------	------	------	------	------

17. Tuesday 1 March 1955

Time 1300 - Observed and recorded gravity and temperature of each cell.

Time 1315 - Made preparations for battery discharge.

Time 1339 - Commenced 40 ampere rate discharge of both batteries simultaneously.

Time 1359 - Secured discharge with 800 ampere-minutes out.

Time 1414 - Commenced charging Group Two battery at 10 ampere rate.

Time 1452 - Commenced charging Group One battery at various rates to produce moderate gassing of cells as follows:

- a) 10.5 minutes at 40 amperes.
- b) 2.0 minutes at 35 amperes.
- c) 2.0 minutes at 30 amperes.
- d) 2.75 minutes at 25 amperes.
- e) 2.0 minutes at 20 amperes.
- f) 6.0 minutes at 15 amperes.
- g) 6.5 minutes at 10 amperes.

Total input 800 ampere minutes.

Time 1534 - Secured charging Group Two battery with 800 ampere-minutes input.

Time 1540 - Observed and recorded gravity and temperature of each cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>B3</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>D1</u>	<u>D2</u>	<u>D3</u>
-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------

CHARGED

Reading:

1211	1201	1207	1211	1204	1204	1212	1208	1208	1196	1211	1218
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

72	72	71	71	71	71	71	71	71	71	71	71
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1208	1198	1207	1208	1201	1201	1209	1205	1205	1193	1208	1215
------	------	------	------	------	------	------	------	------	------	------	------

DISCHARGED

Reading:

1193	1185	1190	1187	1183	1184	1191	1187	1186	1175	1184	1196
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

76	75	74	74	74	74	74	74	74	75	75	75
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1191	1183	1188	1185	1181	1182	1189	1185	1184	1173	1182	1194
------	------	------	------	------	------	------	------	------	------	------	------

RECHARGED

Reading:

1202	1192	1198	1200	1190	1190	1200	1199	1198	1183	1200	1202
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

82	82	81	81	81	80	80	81	80	78	78	78
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1203	1193	1198	1200	1190	1190	1200	1199	1198	1182	1199	1201
------	------	------	------	------	------	------	------	------	------	------	------

PERCENT RECOVERY

Immediately After Charge:

70.5	66.6	52.6	65.2	49.2	42.1	55.0	70.0	66.6	45.0	65.2	33.3
------	------	------	------	------	------	------	------	------	------	------	------

24 Hours After Charge:

100.0	86.5	78.9	60.9	65.0	57.8	75.0	80.0	90.5	55.0	61.5	42.8
-------	------	------	------	------	------	------	------	------	------	------	------

48 Hours After Charge:

117.0	113.2	94.9	100.0	100.0	84.3	110.0	100.0	109.5	95.0	80.8	90.5
-------	-------	------	-------	-------	------	-------	-------	-------	------	------	------

18. Thursday 3 March 1955

Time 1100 - Changed battery groups so that batteries will consist of two groups of six cells each. Group One contains cells A1, A2, A3, B1, B2, and B3. Group Two contains cells C1, C2, C3, D1, D2 and D3.

Time 1300 - Observed and recorded gravity and temperature each cell.

Time 1315 - Commenced simultaneous discharge of both batteries at 30 ampere rate.

Time 1345 - Secured battery discharge with 900 ampere-minutes out.

Time 1350 - Observed and recorded gravity and temperature of each cell.

Time 1409 - Commenced charging Group Two battery at 10 ampere rate.

Time 1422 - Commenced charging Group One battery at various rates to produce moderate gassing as follows:

- a) 11.5 minutes at 40 amperes.
- b) 2.5 minutes at 35 amperes.
- c) 2.5 minutes at 30 amperes.
- d) 4.5 minutes at 25 amperes.
- e) 2.5 minutes at 20 amperes.
- f) 5.0 minutes at 15 amperes.
- g) 4.0 minutes at 10 amperes.

Total input this charge is 900 ampere-minutes.

Time 1539 - Completed charging Group Two battery with 900 ampere-minute input.

Time 1545 - Observed and recorded gravity and temperature of each cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>B3</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>D1</u>	<u>D2</u>	<u>D3</u>
-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------

CHARGED

Reading:

1214	1203	1210	1212	1205	1202	1215	1209	1211	1196	1207	1217
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

70	70	69	69	69	69	69	69	69	68	68	68
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1211	1200	1206	1208	1201	1198	1211	1205	1207	1192	1203	1213
------	------	------	------	------	------	------	------	------	------	------	------

DISCHARGED

Reading:

1194	1186	1190	1190	1184	1182	1197	1187	1188	1173	1184	1196
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

74	73	73	73	73	73	73	72	72	73	73	73
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1192	1184	1188	1188	1182	1180	1195	1184	1185	1171	1182	1194
------	------	------	------	------	------	------	------	------	------	------	------

RECHARGED

Reading:

1207	1192	1197	1206	1195	1194	1200	1197	1194	1175	1194	1198
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

82	82	82	82	82	81	79	78	78	78	78	78
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1208	1193	1198	1207	1196	1194	1199	1196	1193	1174	1193	1197
------	------	------	------	------	------	------	------	------	------	------	------

PERCENT RECOVERY

Immediately After Charge:

84.2	62.5	55.5	95.0	73.6	77.6	25.0	57.2	36.3	14.3	52.3	15.8
------	------	------	------	------	------	------	------	------	------	------	------

5 Days After Charge:

142.0	131.0	122.2	80.0	79.0	123.0	119.0	124.0	104.5	109.5	109.5	115.5
-------	-------	-------	------	------	-------	-------	-------	-------	-------	-------	-------



19. Tuesday 8 March 1955

Time 1130 - Observed and recorded specific gravity and temperature of each cell.

Time 1155 - Made all preparations for discharging batteries.

Time 1200 - Commenced discharge of both battery groups simultaneously at 30 ampere rate.

Time 1230 - Secured battery discharge with 900 ampere minutes taken out.

Time 1235 - Observed and recorded specific gravity and temperature of each cell.

Time 1245 - Made all preparations for charging batteries separately.

Time 1254 - Commenced charging Group Two battery at 10 ampere rate.

Time 1330 - Commenced charging Group One battery at various rates to produce moderate gassing as follows:

- a) 40 amperes for 9.0 minutes.
- b) 35 amperes for 2.5 minutes.
- c) 30 amperes for 3.0 minutes.
- d) 25 amperes for 3.0 minutes.
- e) 20 amperes for 5.5 minutes.
- f) 15 amperes for 6.0 minutes.
- g) 10 amperes for 8.75 minutes.

Total input 900 ampere-minutes this charge.

Time 1408 - Completed charging Group One battery. 900 ampere-minute input.

Time 1424 - Completed charging Group Two battery with 900 ampere-minutes total input this charge.

Time 1435 - Observed and recorded gravity and temperature of each cells.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>B3</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>D1</u>	<u>D2</u>	<u>D3</u>
-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------

CHARGED

Reading:											
1221	1207	1212	1206	1205	1205	1216	1212	1210	1196	1207	1218
Temp.:											
74	74	74	74	74	74	74	74	74	74	74	74
Gravity:											
1219	1205	1210	1204	1203	1203	1214	1210	1208	1194	1205	1216

DISCHARGED

Reading:											
1191	1183	1187	1185	1180	1181	1191	1185	1183	1170	1185	1191
Temp.:											
78	78	78	78	78	78	78	78	78	78	78	78
Gravity:											
1190	1182	1186	1184	1179	1180	1190	1184	1182	1169	1184	1190

RECHARGED

Reading:											
1196	1187	1192	1196	1186	1186	1192	1187	1187	1174	1186	1196
Temp.:											
85	85	85	85	85	85	82	82	82	82	82	82
Gravity:											
1198	1189	1194	1198	1188	1188	1193	1188	1188	1175	1187	1197

PERCENT RECOVERY

Immediately After Charge:											
27.6	30.4	33.3	70.0	37.5	34.8	12.5	15.4	23.1	24.0	14.3	26.9
24 Hours After Charge:											
37.9	39.1	62.5	80.0	45.8	43.5	37.5	50.0	38.5	48.0	47.7	42.3

20. Wednesday 9 March 1955

Time 0900 - Observed and recorded gravity and temperature of each cell.

Time 0915 - Made all preparations for discharging Group One and Group Two batteries.

Time 0920 - Commenced discharging both batteries simultaneously at 30 ampere rate.

Time 0950 - Secured discharging batteries with 900 ampere-minutes out this discharge.

Time 0955 - Observed and recorded temperature and gravity of each cell.

Time 1005 - Made all preparations for charging each battery group separately.

Time 1007 - Commenced charging Group Two battery at 10 ampere rate.

Time 1020 - Commenced charging Group One battery at various rates to produce moderate gassing of cells as follows:

- a) 40 amperes for 10 minutes.
- b) 35 amperes for 3.5 minutes.
- c) 30 amperes for 2.5 minutes.
- d) 25 amperes for 3.5 minutes.
- e) 20 amperes for 5.5 minutes.
- f) 15 amperes for 6.0 minutes.
- g) 10 amperes for 3.0 minutes.

The total input this charge is 900 ampere-minutes.

Time 1137 - Secured charging Group Two battery with total of 900 ampere-minutes input this charge.

Time 1140 - Observed and recorded temperature and gravity of each battery cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

A1 A2 A3 B1 B2 B3 C1 C2 C3 D1 D2 D3

CHARGED

Reading:
 1203 1193 1203 1202 1192 1192 1201 1199 1194 1183 1196 1203
 Temp.:
 74 74 74 74 74 74 74 74 74 74 74
 Gravity:
 1201 1191 1201 1200 1190 1190 1199 1197 1192 1181 1194 1201

DISCHARGED

Reading:
 1186 1198 1185 1181 1181 1175 1186 1179 1177 1165 1173 1185
 Temp.:
 76 76 76 76 76 76 76 76 76 76 76
 Gravity:
 1185 1177 1184 1180 1180 1174 1185 1178 1176 1164 1172 1184

RECHARGED

Reading:
 1198 1185 1192 1198 1185 1185 1190 1187 1184 1170 1187 1189
 Temp.:
 82 82 82 82 82 82 79 78 78 78 78
 Gravity:
 1199 1186 1193 1199 1186 1186 1190 1186 1183 1169 1186 1188

PERCENT RECOVERY

Immediately After Charge:
 87.5 64.2 52.9 95.0 60.0 75.0 35.7 42.1 43.7 17.7 63.6 23.5
 48 Hours After Charge:
 131.0 135.0 106.0 115.0 160.0 150.0 121.0 105.0 106.0 106.0 113.0 112.0

21. Friday 11 March 1955

Time 1200 - Observed and recorded temperature and gravity of each battery cell.

Time 1220 - Made all preparations for discharging both battery groups simultaneously.

Time 1240 - Commenced discharge of both batteries at 30 ampere rate.

Time 1310 - Secured battery discharge with 900 ampere-minutes output this discharge.

Time 1315 - Observed and recorded gravity and temperature of each cells.

Time 1325 - Made all preparations for charging battery groups separately.

Time 1333 - Commenced charging Group Two battery at 10 ampere rate.

Time 1358 - Commenced charging Group One battery at various rates to produce moderate gassing of cells as follows:

- a) 40 amperes for 9.0 minutes.
- b) 35 amperes for 3.5 minutes.
- c) 30 amperes for 3.0 minutes.
- d) 25 amperes for 4.0 minutes.
- e) 20 amperes for 6.0 minutes.
- f) 15 amperes for 7.0 minutes.

Total input this charge is 900 ampere-minutes.

Time 1424 - Group Two battery charge interrupted due to power failure.

Time 1444 - Resumed charging Group Two battery at 10 ampere rate.

Time 1523 - Secured charging Group Two battery. Total input this

charge is 900 ampere-minutes.

Time 1530 - Observed and recorded gravity and temperature of each cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

A1 A2 A3 B1 B2 B3 C1 C2 C3 D1 D2 D3

CHARGED

Reading:

1209 1199 1205 1206 1199 1201 1205 1201 1196 1185 1200 1207

Temp.:

71 71 71 71 71 71 71 71 71 71 71 71

Gravity:

1206 1196 1202 1203 1196 1198 1202 1198 1193 1182 1197 1204

DISCHARGED

Reading:

1187 1176 1184 1176 1173 1171 1185 1177 1175 1164 1173 1183

Temp.:

74 74 74 74 74 74 74 74 74 74 74 74

Gravity:

1185 1174 1182 1174 1171 1169 1183 1175 1173 1162 1171 1181

RECHARGED

Reading:

1192 1182 1187 1196 1186 1185 1187 1184 1181 1168 1185 1186

Temp.:

82 82 82 82 82 82 78 78 78 78 78 78

Gravity:

1193 1183 1188 1197 1187 1186 1186 1183 1180 1167 1184 1185

PERCENT RECOVERY

Immediately After Charge:

38.1 40.8 30.0 121.0 64.0 58.6 15.8 34.8 35.0 25.0 50.0 17.4

4 Days After Charge:

104.5 109.0 130.0 147.5 112.0 107.0 152.5 134.8 150.0 150.0 111.4 134.8

22. Tuesday 22 March 1955

Time 1200 - Resumed experiment after interruption due to intercession-
at period special orientation course lectures.

Time 1300 - Observed and recorded temperature and gravity of each
cell.

Time 1305 - Made all preparations for discharging batteries.

Time 1311 - Commenced 30 ampere rate discharge of both battery groups
simultaneously.

Time 1341 - Secured discharge with 900 ampere-minutes output from
batteries.

Time 1345 - Observed and recorded the gravity and temperature
of each cell.

Time 1355 - Made all preparations for charging each battery group
separately.

Time 1401 - Commenced charging Group Two Battery at 10 ampere rate.

Time 1415 - Commenced charging Group One Battery at various rates
to produce moderate gassing as follows:

- a) 40 amperes for 11 minutes.
- b) 35 amperes for 5.5 minutes.
- c) 30 amperes for 3.0 minutes.
- d) 25 amperes for 3.0 minutes.
- e) 20 amperes for 5.0 minutes.

Total input is 900 ampere-minutes.

Time 1531 - Completed charging Group Two battery with 900 ampere-
minute input this charge.

Time 1545 - Observed and recorded gravity and temperature of each
battery cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>B3</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>D1</u>	<u>D2</u>	<u>D3</u>
-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------

CHARGED

Reading:

1206	1198	1208	1202	1199	1200	1212	1206	1203	1193	1201	1213
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

82	81	81	81	80	80	80	79	79	78	78	78
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1207	1198	1208	1202	1199	1200	1212	1206	1203	1192	1200	1212
------	------	------	------	------	------	------	------	------	------	------	------

DISCHARGED

Reading:

1182	1171	1175	1172	1163	1167	1180	1173	1172	1163	1169	1181
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

82	82	81	80	80	80	80	80	79	79	78	78
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1183	1172	1175	1172	1163	1167	1180	1173	1172	1163	1168	1180
------	------	------	------	------	------	------	------	------	------	------	------

RECHARGED

Reading:

1191	1180	1187	1192	1178	1181	1184	1175	1174	1165	1173	1182
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

84	85	84	84	84	83	78	78	78	77	78	77
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1192	1182	1188	1193	1179	1182	1183	1174	1173	1164	1172	1181
------	------	------	------	------	------	------	------	------	------	------	------

PERCENT RECOVERY

Immediately After Charge:

37.5	38.5	39.4	70.0	44.5	45.5	9.38	3.03	3.23	3.45	12.5	3.13
------	------	------	------	------	------	------	------	------	------	------	------

24 Hours After Charge:

37.5	46.2	54.5	76.7	52.8	57.5	18.7	30.3	22.6	24.1	40.6	25.0
------	------	------	------	------	------	------	------	------	------	------	------

23. Wednesday 23 March 1955

Time 0845 - Observed and recorded individual gravity and temperature of each battery cell.

Time 0900 - Made all preparations for discharging batteries.

Time 0915 - Commenced discharge of both battery groups simultaneously at a 30 ampere rate.

Time 0940 - Secured battery discharge with 750 ampere-minute output this discharge.

Time 0945 - Observed and recorded gravity and temperature of each battery cell.

Time 0955 - Made all preparations for charging battery groups separately.

Time 0958 - Commenced charging Group Two battery at 10 ampere rate.

Time 1010 - Commenced charging Group One battery at various rates to produce moderate gassing as follows:

- a) 45 amperes for 2.0 minutes.
- b) 40 amperes for 5.5 minutes.
- c) 35 amperes for 2.0 minutes.
- d) 30 amperes for 2.0 minutes.
- e) 25 amperes for 4.0 minutes.
- f) 20 amperes for 5.0 minutes.
- g) 15 amperes for 7.35 minutes.

Total input this charge is 750 ampere-minutes.

Time 1113 - Secured charge to Group Two battery with total input of 750 ampere minutes this charge.

Time 1125 - Observed and recorded the gravity and temperature of each battery cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

A1 A2 A3 B1 B2 B3 C1 C2 C3 D1 D2 D3

CHARGED

Reading:

1196 1188 1197 1199 1186 1190 1190 1187 1183 1174 1185 1192

Temp.:

69 69 68 68 68 68 68 68 68 68 68 68

Gravity:

1192 1184 1193 1195 1182 1186 1186 1183 1179 1170 1181 1188

DISCHARGED

Reading:

1185 1179 1181 1177 1172 1171 1185 1178 1173 1164 1172 1182

Temp.:

70 70 70 70 70 70 70 70 70 69 70 71

Gravity:

1182 1176 1178 1174 1169 1168 1182 1175 1170 1160 1169 1179

RECHARGED

Reading:

1189 1184 1188 1194 1181 1182 1184 1184 1181 1173 1186 1186

Temp.:

76 76 76 76 76 76 73 72 72 73 73 72

Gravity:

1188 1183 1187 1195 1180 1181 1182 1181 1178 1171 1184 1183

PERCENT RECOVERY

Immediately After Charge:

60.0 87.5 60.0 90.5 84.5 72.3 0.0 75.0 89.0 110.0 125.0 44.0

24 Hours After Charge:

160.0 112.5 66.6 100.0 138.5 88.9 200.0 162.5 144.4 120.0 150.0 155.5

24. Thursday 24 March 1955

Time 1215 - Observed and recorded specific gravity and temperature of each cell.

Time 1229 - made all preparations for discharging batteries simultaneously.

Time 1238 - commenced 30 ampere rate discharge of both battery groups.

Time 1308 - Secured discharging batteries with 900 ampere-minutes output from each battery group.

Time 1310 - Observed and recorded the temperature and specific gravity of each cell.

Time 1315 - made all preparations for charging each battery group separately.

Time 1321 - Commenced charging Group Two battery at 10 ampere rate.

Time 1331 - Commenced charging Group One battery at various rates to produce moderate gassing of cells as follows:

- a) 45 ampere rate for 8.0 minutes.
- b) 40 ampere rate for 2.0 minutes.
- c) 35 amperes for 3.0 minutes.
- d) 30 amperes for 4.0 minutes.
- e) 25 amperes for 4.0 minutes.
- f) 20 amperes for 7.75 minutes.

Total input this charge is 900 ampere-minutes.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>B3</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>D1</u>	<u>D2</u>	<u>D3</u>
-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------

CHARGED

Reading:	1201	1188	1191	1198	1190	1187	1193	1191	1186	1175	1190	1196
Temp.:	71	70	70	70	70	70	70	70	70	70	70	70
Gravity:	1198	1185	1188	1195	1187	1184	1190	1188	1183	1172	1187	1193

DISCHARGED

Reading:	1177	1168	1173	1171	1166	1164	1179	1173	1168	1160	1168	1178
Temp.:	72	72	72	72	72	72	72	72	72	72	72	72
Gravity:	1174	1165	1170	1168	1163	1161	1176	1170	1165	1157	1165	1178

RECHARGED

Reading:	1193	1181	1187	1191	1182	1181	1181	1174	1173
Temp.:	76	76	76	76	76	74	74	74	
Gravity:	1192	1180	1186	1190	1181	1180	1179	1172	1171

PERCENT RECOVERY

Immediately After Charge:	75.0	75.0	89.0	81.5	75.0	82.6	21.4	11.1	33.0
48 Hours After Charge:	95.8	115.0	127.8	92.5	91.7	104.5	85.7	77.8	94.5

25. Saturday 26 March 1955

Time 1245 - Observed and recorded specific gravity and temperature of each battery cell.

Time 1300 - Made all preparations for discharging both battery groups.

Time 1315 - Commenced discharging both battery groups simultaneously, at the 30 ampere rate.

Time 1335 - Completed discharging batteries with 750 ampere-minute output this charge.

Time 1337 - Observed and recorded temperature and specific gravity of each cell.

Time 1347 - Made all preparations for charging batteries in their individual groups.

Time 1353 - Commenced charging Group Two battery at the 10 ampere rate.

Time 1402 - Commenced charging Group One battery at various rates to produce moderate gassing as follows:

- a) 45 amperes for 8.0 minutes.
- b) 40 amperes for 1.0 minutes.
- c) 35 amperes for 3.5 minutes.
- d) 30 amperes for 4.0 minutes.
- e) 25 amperes for 4.25 minutes.

Total input this charge is 750 ampere-minutes.

Time 1518 - Completed charging Group Two battery at 10.0 ampere rate. Total input this charge is 750 ampere-minutes.

Time 1522 - Observed and recorded the specific gravity and temperature of each battery cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

A1 A2 A3 B1 B2 B3 C1 C2 C3 D1 D2 D3

CHARGED

Reading:

1198 1190 1195 1195 1187 1187 1190 1186 1184 1175 1189 1194

Temp.:

76 75 75 75 75 75 75 75 75 74 74 74

Gravity:

1197 1188 1193 1193 1185 1185 1188 1184 1182 1173 1187 1192

DISCHARGED

Reading:

1180 1171 1175 1170 1166 1165 1179 1172 1169 1160 1167 1177

Temp.:

77 77 77 77 77 77 77 77 77 77 77 77

Gravity:

1179 1170 1174 1169 1165 1164 1178 1171 1168 1159 1166 1176

RECHARGED

Reading:

1195 1185 1187 1187 1183 1179 1185 1180 1181 1175 1186 1185

Temp.:

84 84 84 84 84 84 80 80 80 80 80 80

Gravity:

1196 1186 1188 1188 1184 1180 1185 1180 1181 1175 1186 1185

PERCENT RECOVERY

Immediately After Charge:

94.5 88.9 73.7 79.2 95.0 76.3 70.0 69.2 92.9 114.2 95.5 50.0

24 Hours After Charge:

94.5 94.5 89.5 91.7 110.0 100.0 110.0 100.0 114.3 121.5 114.3 83.4

26. Sunday 27 March 1955

Time 1315 - Observed and recorded temperature and specific gravity of each battery cell.

Time 1329 - Made all preparations for discharging batteries simultaneously.

Time 1345 - Commenced discharge of both battery groups at the 30 ampere rate.

Time 1410 - Completed battery discharge with total output 750 ampere-minutes for this discharge.

Time 1411 - Observed and recorded the specific gravity and temperature of each battery cell.

Time 1415 - Made all preparations for charging the batteries in their individual battery groups.

Time 1416 - Commenced charging Group Two battery at a 10 ampere rate.

Time 1431 - Commenced charging Group One battery at various rates to produce moderate gassing as follows:

- a) 45 amperes for 7.00 minutes.
- b) 40 amperes for 2.5 minutes.
- c) 35 amperes for 2.5 minutes.
- d) 30 amperes for 2.0 minutes.
- e) 25 amperes for 4.0 minutes.
- f) 20 amperes for 4.4 minutes.

Total input this charge is 750 ampere-minutes.

Time 1531 - Secured charging Group Two battery with total input this charge at 750 ampere-minutes.

Time 1532 - Observed and recorded the specific gravity and temperature of each battery cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

A1 A2 A3 B1 B2 B3 C1 C2 C3 D1 D2 D3

CHARGED

Reading:

1197 1188 1192 1192 1188 1186 1190 1185 1185 1177 1191 1192

Temp.:

77 76 76 76 76 76 76 76 76 76 76 76

Gravity:

1196 1187 1191 1191 1187 1185 1189 1184 1184 1176 1190 1191

DISCHARGED

Reading:

1165 1174 1172 1169 1164 1160 1184 1176 1172 1164 1172 1180

Temp.:

78 78 78 78 78 78 78 78 78 78 78 78

Gravity:

1164 1173 1171 1166 1163 1159 1183 1175 1171 1163 1171 1179

RECHARGED

Reading:

1192 1180 1181 1185 1180 1173 1184 1174 1174 1169 1180 1183

Temp.:

84 84 84 84 84 84 80 80 80 80 80 80

Gravity:

1193 1181 1182 1186 1181 1174 1184 1174 1174 1169 1180 1183

PERCENT RECOVERY

Immediately After Charge:

132.0 78.5 55.0 80.0 75.0 57.6 16.6 -11.1 23.1 46.1 47.4 33.3

48 Hours After Charge:

141.0 121.3 75.0 72.0 66.7 84.6 150.0 100.0 100.0 100.0 100.0 100.0

27. Tuesday 29 March 1955

Time 1324 - Observed and recorded the specific gravity and temperature of each battery cell.

Time 1337 - Made all preparations for discharging both battery groups.

Time 1343 - Commenced discharging both Group One and Group Two batteries simultaneously at the 30 ampere rate.

Time 1408 - Secured discharging batteries with 750 ampere-minute output this discharge.

Time 1410 - Observed and recorded specific gravity and temperature of each battery cell.

Time 1414 - Made all preparations for charging each battery group separately.

Time 1416 - Commenced charging Group Two battery at 10 ampere rate.

Time 1430 - Commenced charging Group One battery at various rates to produce moderate gassing as follows:

- a) 45 amperes for 7.0 minutes.
- b) 40 amperes for 3.0 minutes.
- c) 35 amperes for 3.0 minutes.
- d) 30 amperes for 3.0 minutes.
- e) 25 amperes for 5.0 minutes.
- f) 20 amperes for 7.25 minutes.

Total input this charge is 900 ampere minutes.

Time 1546 - Secured charging Group Two battery. Total input this charge is 900 ampere-minutes.

Time 1550 - Observed and recorded specific gravity and temperature of each battery cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>B3</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>D1</u>	<u>D2</u>	<u>D3</u>
-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------

CHARGED

Reading:

1196	1188	1191	1185	1184	1182	1193	1188	1185	1175	1189	1196
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

76	76	76	76	76	76	76	76	76	76	76	76
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1195	1187	1190	1184	1183	1181	1192	1187	1184	1174	1188	1195
------	------	------	------	------	------	------	------	------	------	------	------

DISCHARGED

Reading:

1174	1165	1169	1165	1163	1159	1187	1176	1172	1166	1169	1179
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

78	78	78	78	78	78	78	78	78	78	78	78
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1173	1164	1168	1164	1162	1158	1186	1175	1171	1165	1168	1178
------	------	------	------	------	------	------	------	------	------	------	------

RECHARGED

Reading:

1197	1185	1186	1186	1184	1179	1191	1187	1186	1185	1193	1188
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

86	86	86	86	86	86	82	82	82	82	82	82
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1199	1187	1188	1188	1186	1181	1192	1188	1187	1186	1194	1189
------	------	------	------	------	------	------	------	------	------	------	------

PERCENT RECOVERY

Immediately After Charge:

118.1	100.0	90.0	120.0	114.0	100.0	100.0	108.0	123.0	234.0	130.0	64.6
-------	-------	------	-------	-------	-------	-------	-------	-------	-------	-------	------

24 Hours After Charge:

118.1	113.0	95.5	130.0	128.5	113.0	100.0	133.2	130.8	200.0	140.0	105.9
-------	-------	------	-------	-------	-------	-------	-------	-------	-------	-------	-------

28. Wednesday 30 March 1955

Time 0900 - Observed and recorded the specific gravity and temperature of each battery cell.

Time 0917 - Made all preparations for discharging batteries.

Time 0952 - Commenced discharging both battery groups simultaneously at the 30 ampere rate.

Time 1017 - Secured discharge of both battery groups with total output this discharge at 750 ampere-minutes.

Time 1019 - Observed and recorded specific gravity and temperature of each battery cell.

Time 1023 - Made all preparations for charging each battery group separately.

Time 1026 - Commenced charging Group Two battery at 10 ampere rate.

Time 1041 - Commenced charging Group One battery at various rates to produce moderate gassing as follows:

- a) 45 amperes for 7.0 minutes.
- b) 40 amperes for 2.0 minutes.
- c) 35 amperes for 2.0 minutes.
- d) 30 amperes for 4.0 minutes.
- e) 25 amperes for 5.0 minutes.
- f) 20 amperes for 7.0 minutes.
- g) 15 amperes for 3.3 minutes.

Total input this charge is 900 ampere-minutes.

Time 1156 - Completed charging Group Two battery with total input this charge at 900 amperes.

Time 1205 - Observed and recorded the specific gravity and temperature of each battery cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

A1 A2 A3 B1 B2 B3 C1 C2 C3 D1 D2 D3

CHARGED

Reading:
 1201 1192 1191 1192 1191 1186 1197 1193 1190 1185 1198 1198
 Temp.:
 74 74 74 74 74 74 74 74 74 74 74 74
 Gravity:
 1199 1190 1189 1190 1189 1184 1195 1191 1188 1183 1196 1196

DISCHARGED

Reading:
 1177 1168 1172 1168 1166 1162 1188 1181 1175 1170 1179 1184
 Temp.:
 77 76 76 76 76 76 76 76 76 76 76 76
 Gravity:
 1176 1167 1171 1167 1165 1161 1187 1180 1174 1169 1178 1183

RECHARGED

Reading:
 1203 1192 1192 1191 1190 1185 1193 1191 1189 1183 1194 1194
 Temp.:
 82 84 83 83 83 83 80 80 80 80 80 80
 Gravity:
 1204 1193 1193 1192 1191 1186 1193 1191 1189 1183 1194 1194

PERCENT RECOVERY

Immediately After Charge:
 122.0 113.0 122.0 65.2 185.0 108.5 75.0 100.0 107.0 100.0 88.9 84.6
 24 Hours After Charge:
 139.1 147.8 155.5 78.3 221.0 117.4 137.5 136.3 128.5 114.3 81.9 154.0

29. Thursday 31 March 1955

Time 1255 - Observed and recorded specific gravity and temperature of each battery cell.

Time 1307 - Made all preparations for discharging battery groups.

Time 1320 - Commenced discharging both battery groups simultaneously at the 30 ampere rate.

Time 1345 - Completed discharge of batteries with total output this discharge at 750 ampere minutes.

Time 1346 - Observed and recorded specific gravity and temperature of each battery cell.

Time 1350 - Made all preparations for charging batteries in their individual battery groups.

Time 1351 - Commenced charging Group Two battery at the 10 ampere rate.

Time 1402 - Commenced charging Group One battery at various rates to produce moderate gassing as follows:

- a) 45 ampere rate for 8.9 minutes.
- b) 40 ampere rate for 2.0 minutes.
- c) 35 amperes for 2.0 minutes.
- d) 30 amperes for 5.0 minutes.
- e) 25 amperes for 3.0 minutes.
- f) 20 amperes for 8.0 minutes.

Total input this charge is 895 ampere-minutes.

Time 1517 - Completed charge of Group Two battery with total input this charge at 895 ampere-minutes.

Time 1523 - Observed and recorded the specific gravity and temperature of each battery cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

A1 A2 A3 B1 B2 B3 C1 C2 C3 D1 D2 D3

CHARGED

Reading:
 1210 1203 1201 1197 1198 1190 1200 1197 1194 1187 1202 1205
 Temp.:
 73 73 73 73 73 73 73 73 73 73 73 73
 Gravity:
 1208 1201 1199 1195 1196 1188 1198 1195 1192 1185 1200 1203

DISCHARGED

Reading:
 1182 1174 1174 1168 1169 1167 1190 1184 1180 1171 1181 1186
 Temp.:
 75 75 75 75 75 75 75 75 75 75 75 75
 Gravity:
 1180 1172 1172 1166 1167 1165 1188 1182 1178 1169 1179 1184

RECHARGED

Reading:
 1205 1195 1200 1190 1190 1190 1199 1195 1195 1185 1205 1205
 Temp.:
 84 84 84 84 84 84 80 80 80 80 80 80
 Gravity:
 1206 1196 1201 1191 1191 1191 1199 1195 1195 1185 1205 1205

PERCENT RECOVERY

Immediately After Charge:
 93.0 82.8 107.2 86.1 82.8 113.0 110.0 100.0 121.0 100.0 124.0 110.0
 7 Days After Charge:
 85.7 89.7 88.9 103.3 93.2 126.0 230.0 177.0 150.0 168.5 133.0 131.5

30. Thursday 7 April 1955

Time 0853 - Observed and recorded specific gravity and temperature of each battery cell.

Time 0906 - Made all preparations for discharging both batteries simultaneously.

Time 0918 - Commenced discharging both battery groups at the 30 ampere rate.

Time 0943 - Secured discharging batteries with total output of 750 ampere-minutes.

Time 0945 - Observed and recorded the specific gravity and temperature of each battery cell.

Time 0955 - Made all preparations for charging batteries in their individual battery groups.

Time 0958 - Commenced charging Group Two battery at the 10 ampere rate.

Time 1010 - Commenced charging Group One battery at various rates to produce moderate gassing as follows:

- a) 45 amperes for 6.0 minutes.
- b) 40 amperes for 1.0 minutes.
- c) 35 amperes for 3.5 minutes.
- d) 30 amperes for 3.5 minutes.
- e) 25 amperes for 6.0 minutes.
- f) 20 amperes for 6.5 minutes.
- g) 15 amperes for 6.5 minutes.

Total input this charge is 900 ampere-minutes.

Time 1116 - Reduced charging rate to 4.0 amperes for Group Two battery. Running total input this charge is 780 ampere-minutes.

Time 1146 - Secured charge to Group Two battery with total input this charge at 900 ampere minutes.

Time 1147 - Observed and recorded specific gravity and temperature of each battery cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

A1 A2 A3 B1 B2 B3 C1 C2 C3 D1 D2 D3

CHARGED

Reading:
 1207 1201 1199 1199 1197 1197 1214 1208 1202 1199 1210 1212
 Temp.:
 72 72 72 72 72 72 72 72 72 72 72 72
 Gravity:
 1204 1198 1196 1196 1194 1194 1211 1205 1199 1196 1207 1209

DISCHARGED

Reading:
 1185 1176 1183 1171 1168 1168 1187 1179 1175 1173 1180 1187
 Temp.:
 74 74 74 74 74 74 74 74 74 74 74 74
 Gravity:
 1183 1174 1181 1169 1166 1166 1185 1177 1173 1171 1178 1185

RECHARGED

Reading:
 1205 1195 1196 1190 1190 1188 1200 1193 1190 1185 1200 1197
 Temp.:
 82 82 82 82 82 82 78 78 78 78 78 78
 Gravity:
 1206 1196 1197 1191 1191 1189 1199 1192 1189 1184 1199 1196

PERCENT RECOVERY

Immediately After Charge:
 109.5 91.5 106.5 81.5 89.3 82.2 53.8 53.5 61.5 52.0 72.4 45.8
 6 Days After Charge:
 104.8 100.0 146.5 89.0 82.2 85.6 96.2 100.0 107.5 92.0 89.6 116.5

31. Wednesday April 13 1955

Time 0845 - Observed and recorded specific gravity and temperature of each battery cell.

Time 0905 - Made all preparations for discharging both battery groups.

Time 0913 - Commenced discharging both battery groups simultaneously at the 30 ampere rate.

Time 0939 - Secured battery discharge with 780 ampere-minutes output this discharge.

Time 0945 - Observed and recorded specific gravity and temperature of each battery cell.

Time 0957 - Made all preparations for charging both battery groups separately.

Time 1022 - Commenced charging Group Two battery at 10 ampere rate.

Time 1044 - Commenced charging Group One battery at various rates to produce moderate gassing as follows:

- a) 45 amperes for 6.0 minutes.
- b) 40 amperes for 4.0 minutes.
- c) 35 amperes for 3.0 minutes.
- d) 30 amperes for 7.5 minutes.
- e) 20 amperes for 13.5 minutes.

Total input this charge is 925 ampere-minutes.

Time 1152 - Secured charge to Group Two battery with total input this charge at 925 ampere-minutes.

Time 1230 - Observed and recorded the specific gravity and temperature of each battery cell.

NOTE: SEE NEXT PAGE FOR DATA THIS DATE.

CELL:

<u>A1</u>	<u>A2</u>	<u>A3</u>	<u>B1</u>	<u>B2</u>	<u>B3</u>	<u>C1</u>	<u>C2</u>	<u>C3</u>	<u>D1</u>	<u>D2</u>	<u>D3</u>
-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------	-----------

CHARGED

Reading:

1208	1201	1206	1196	1192	1193	1213	1208	1204	1197	1207	1216
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

72	72	72	72	72	72	72	72	72	72	72	72
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1205	1198	1203	1193	1189	1190	1210	1205	1201	1194	1204	1213
------	------	------	------	------	------	------	------	------	------	------	------

DISCHARGED

Reading:

1175	1168	1173	1163	1163	1162	1197	1183	1178	1171	1176	1184
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

75	75	75	75	75	75	75	75	75	75	75	75
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1173	1166	1171	1161	1161	1160	1185	1181	1176	1169	1174	1182
------	------	------	------	------	------	------	------	------	------	------	------

RECHARGED

Reading:

1205	1197	1201	1190	1190	1190	1205	1200	1200	1190	1205	1203
------	------	------	------	------	------	------	------	------	------	------	------

Temp.:

82	84	83	83	83	83	79	79	79	79	79	79
----	----	----	----	----	----	----	----	----	----	----	----

Gravity:

1206	1198	1202	1191	1191	1191	1205	1200	1200	1190	1205	1203
------	------	------	------	------	------	------	------	------	------	------	------

PERCENT RECOVERY

Immediately After Charge:

103.0	100.0	97.0	93.6	107.0	103.0	80.0	79.2	96.0	84.0	103.0	67.7
-------	-------	------	------	-------	-------	------	------	------	------	-------	------

24 Hours After Charge:

93.9	96.9	100.0	103.0	125.0	113.2	92.0	91.6	96.0	108.0	106.7	80.7
------	------	-------	-------	-------	-------	------	------	------	-------	-------	------

CHAPTER IV

DETAILED ANALYSIS, FINAL EVALUATION AND CONCLUSIONS

1. Basis For Analysis.

The data beginning with the cycle on 19 February is deemed the most appropriate starting point for careful analysis. That which is recorded prior to that date will be considered for random purposes aside from the main investigation where necessary. In considering the analysis which follows, the main interest should be directed towards the specific gravities. They will be the primary criteria utilized to evaluate the charging procedure. It must be recognized that other factors in addition to specific gravity are pertinent. However, it is judged that an evaluation of a forced gassing partial charging procedure can be suitably made on the basis of specific gravity alone.

2. Saturday 19 February 1955.

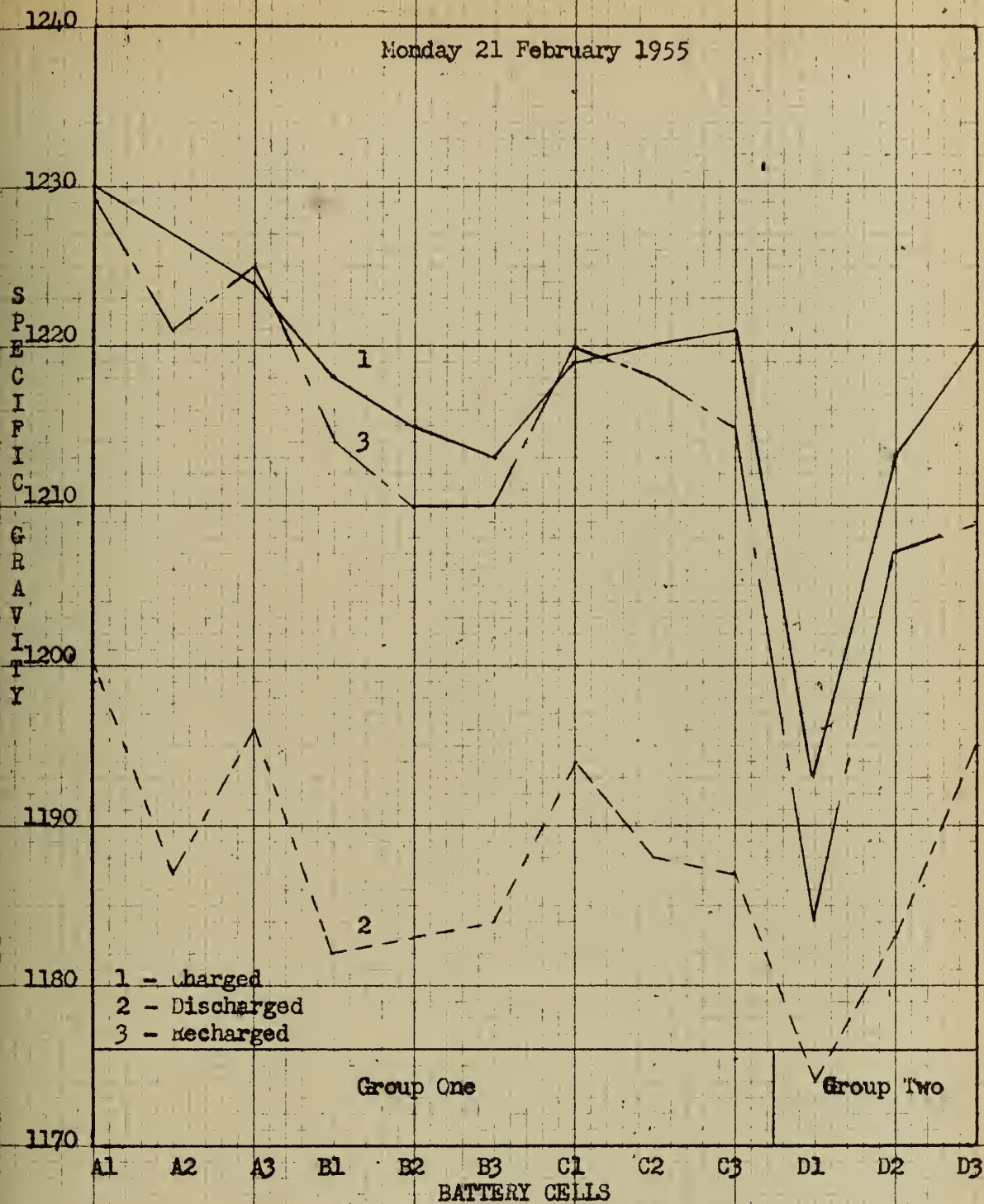
The discharge starts from near the fully charged condition. Both Group One and Group Two cells drop about the same amount in gravity during discharge. During charge the cells all rise nearly the same amount with a slight advantage for Group One, the gassing cells, shown by data taken immediately following completion of the charge. Comparison of both charging methods 48 hours after completion of the charge again shows a slight advantage in favor of the forced gassing charge.

3. Monday 21 February 1955.

As in the previous cycle, the specific gravity dropped nearly the same amount in both groups during the discharge. This appears to indicate a good balance in the condition of cells in both groups. The data



Monday 21 February 1955



Percent Recovery (Order A1 - D3)

Immediately After Charge:

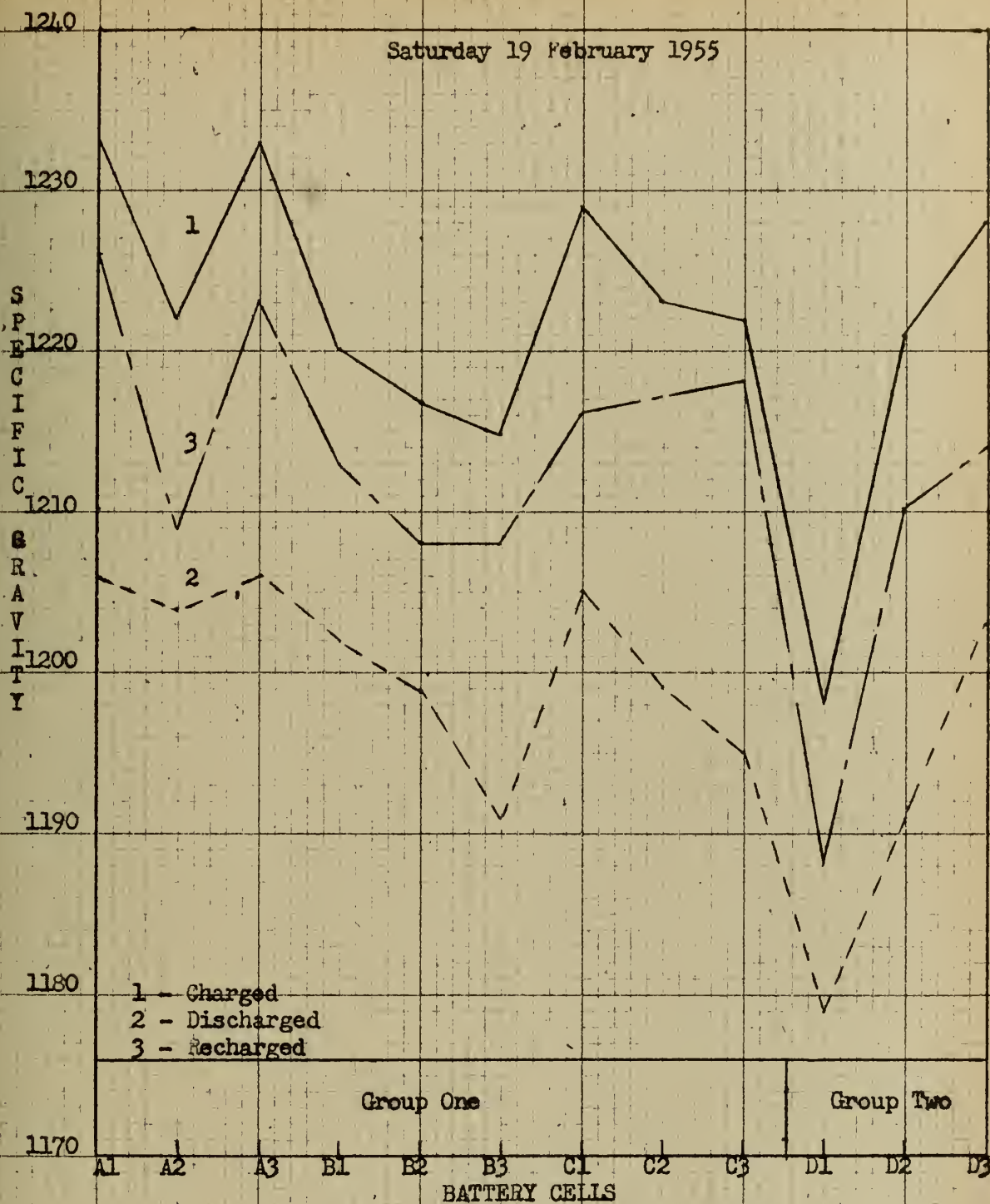
96.8 200.0 96.6 88.9 81.9 89.6 104.0 93.9 82.3 52.6 80.0 56.0

48 Hours After Charge:

100.0 136.8 114.0 89.0 87.5 89.6 116.0 100.0 91.2 100.0 93.2 80.0

Note: Line No. 3 represents gravity immediately after charge.

Saturday 19 February 1955



Percent Recovery (Order A1 - D3)

Immediately After Charge:

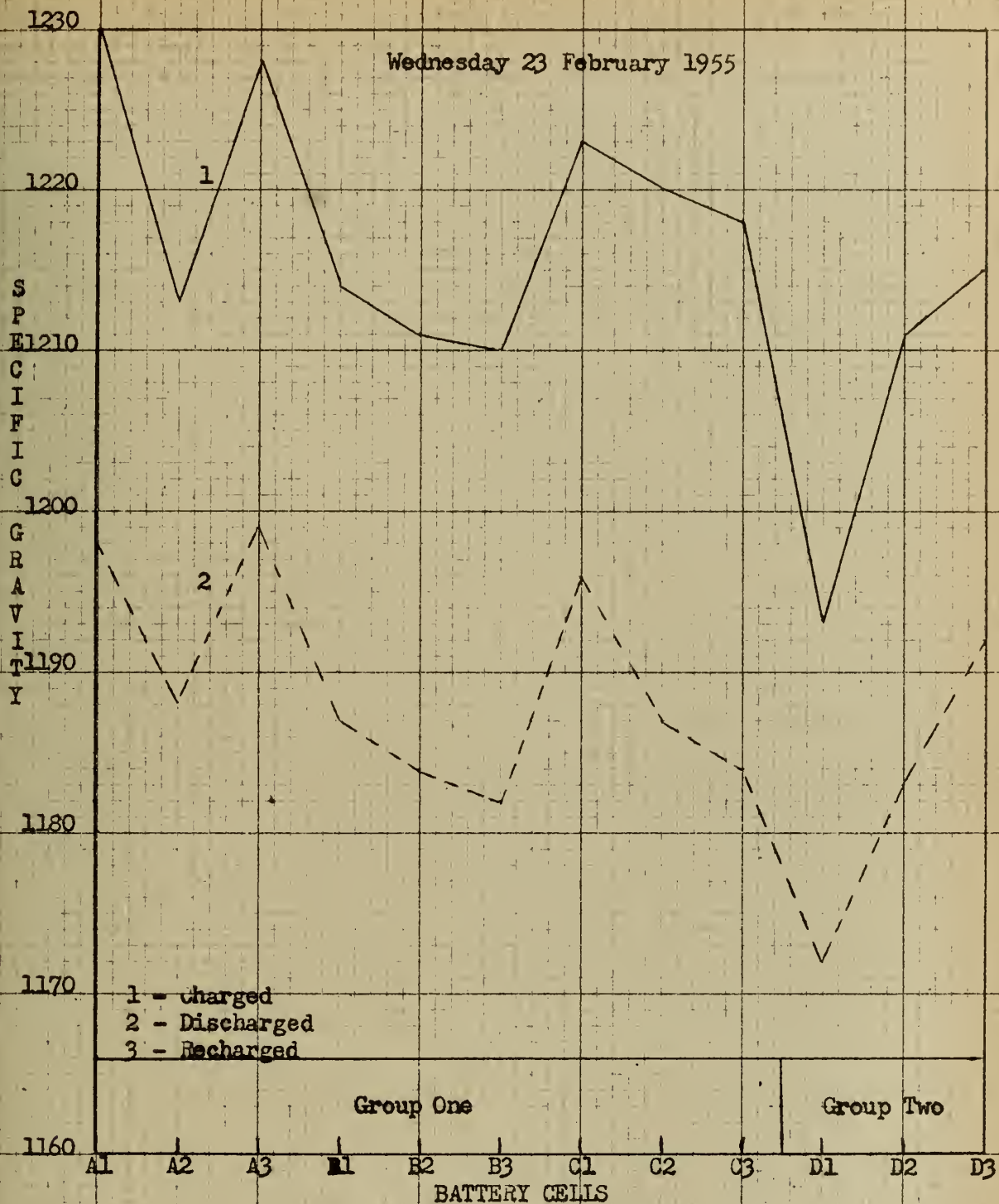
74.1 27.8 63.0 61.1 50.0 70.8 45.9 75.0 85.2 47.4 63.3 44.0

48 Hours After Charge:

88.9 11.1 66.7 88.9 88.9 91.7 58.3 87.4 96.4 73.7 73.5 68.0

Note: Line No. 3 represents gravity immediately after charge.

Wednesday 23 February 1955



Percent Recovery (Order A1 - D3)

Immediately After Charge: No data.

48 Hours After Charge: No data.

Note: Controlled charge interrupted by connector casualty. Next charge to be normal charge to standard gravity.

taken immediately after completion of the charging process is markedly in favor of the forced gassing charge. However, the data taken 48 hours after completion of this charge when the electrolyte had time to equalize in the Group Two cells there was no definite advantage indicated.

4. Friday 25 February 1955.

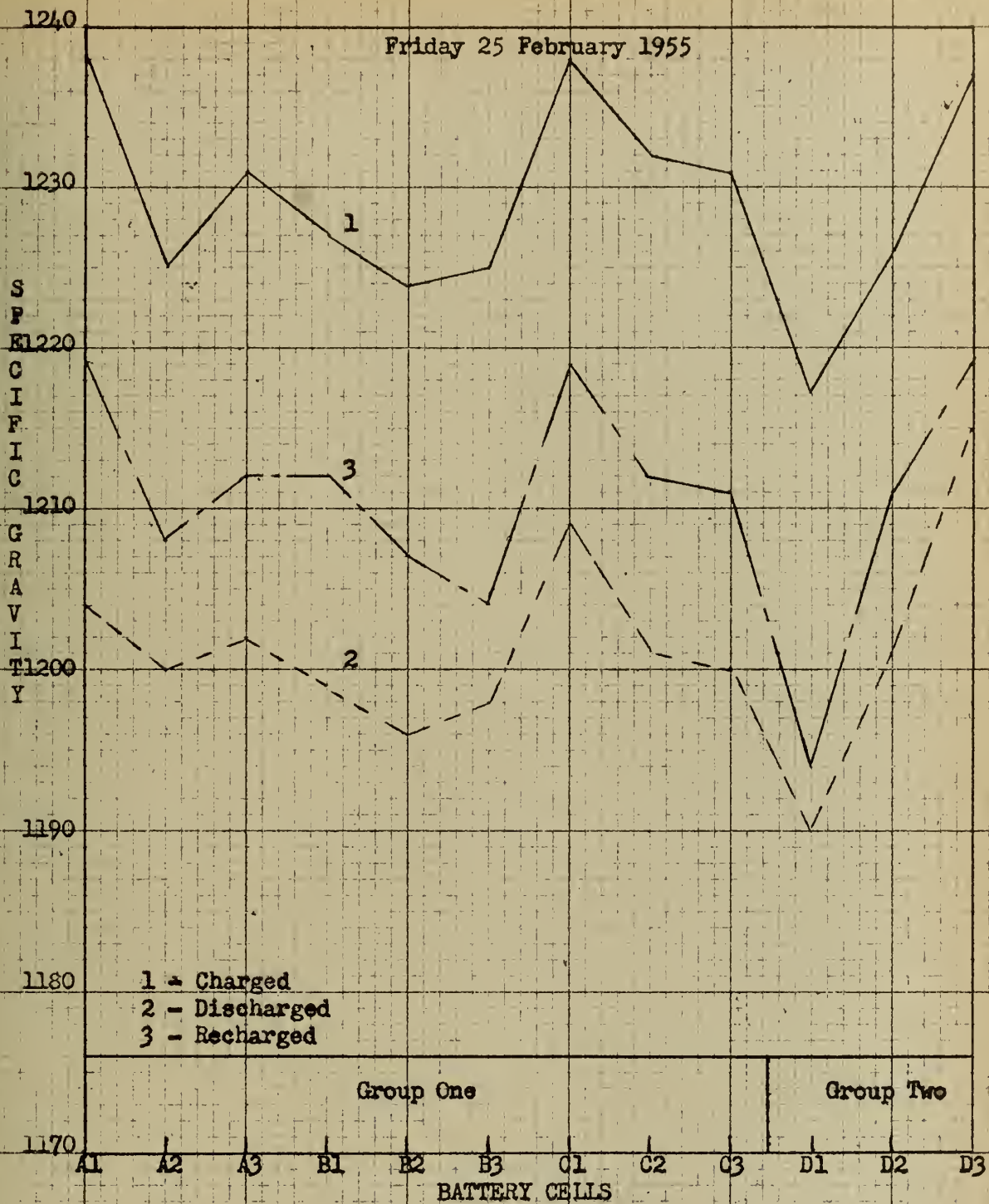
Group One cells show a slightly greater average drop in gravity during this discharge. This could be indicative of ill effects resulting from charging procedure. No advantage is indicated for either method of charging based on the data taken immediately upon securing the charge. Data taken 24 hours after completion of the charge likewise shows no advantage for either charging method used.

5. Saturday 26 February 1955.

Except for cell D1 which has had a notably lower specific gravity than the other cells since it was first place in service, the specific gravities have dropped nearly the same amount from their original level in both battery groups during the series of partial charges thus far. The gravities as measured at end of discharge show a definitely greater drop in the Group One cells than in the Group Two cells. Upon completion of the charging for this cycle, the measured gravities indicate a definitely better recovery in the Group Two cells. The results as observed and recorded 48 hours after completion of charging still indicate a better recovery in Group Two cells than in those of Group One which were charged by the forced gassing method.

6. Monday 28 February 1955.

The average net drop in gravity from the original fully charged condition is 12 points in both cell groups. Contrary to the preceding



Percent Recovery (Order A1 - D3)

Immediately After Charge:

44.1 32.0 34.5 46.5 39.9 22.2 34.5 36.7 36.7 14.8 40.0 23.5

24 Hours After Charge:

58.8 52.0 51.8 39.3 39.3 29.6 38.0 50.0 46.7 25.9 40.0 29.4

Note: Line No. 3 represents gravity immediately after charge.

1240

Saturday 26 February 1955

1230

SPECIFIC GRAVITY

1220

1210

1200

1190

1180

- 1 - Charged
2 - Discharged
3 - Recharged

Group One

Group Two

1170

A1 A2 A3 B1 B2 B3 C1 C2 C3 D1 D2 D3

BATTERY CELLS

Percent Recovery (Order A1 - D3)

Immediately After Charge:

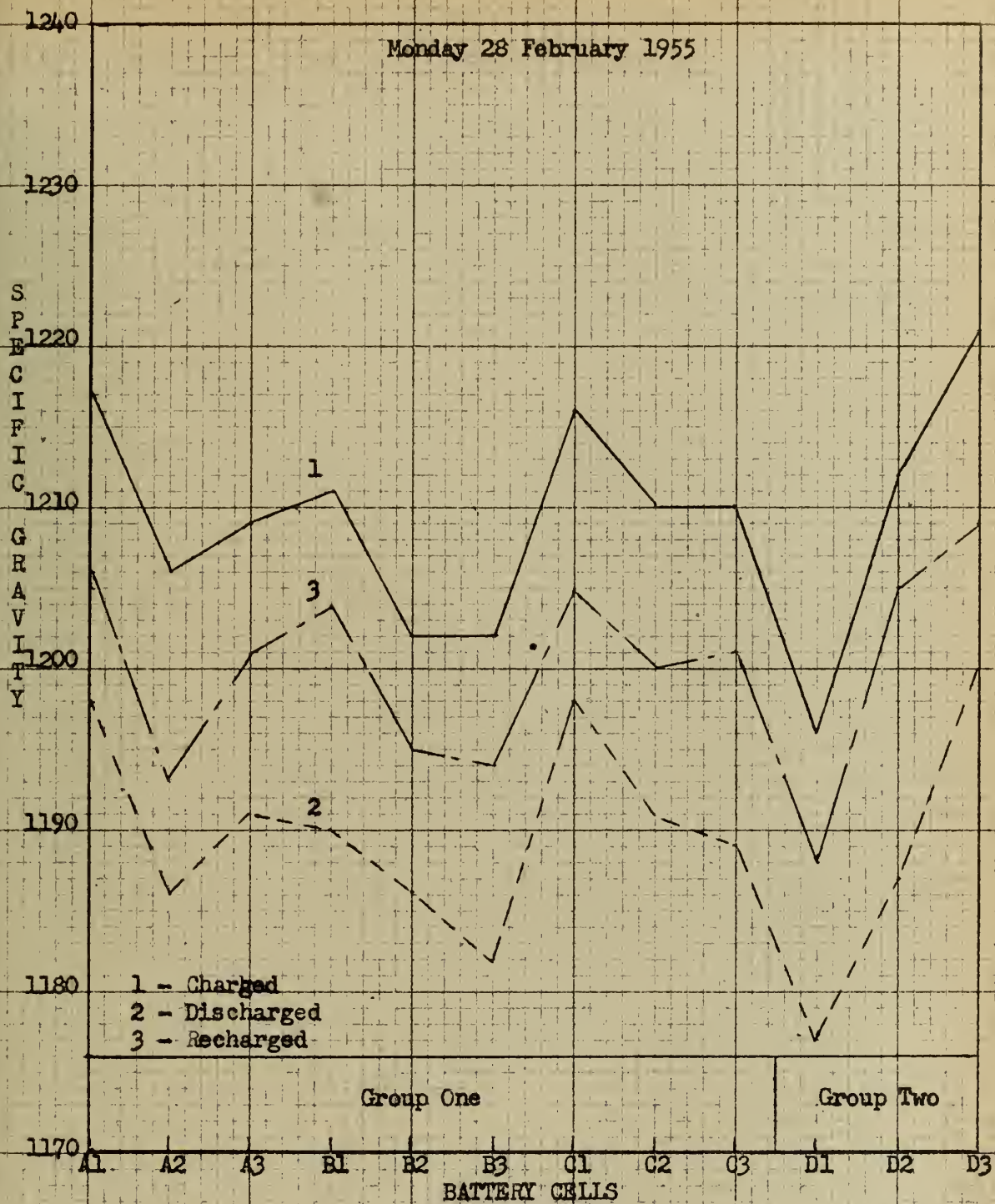
31.8 20.0 21.0 73.4 45.0 53.0 47.4 33.3 55.0 80.0 61.5 61.5

48 Hours After Charge:

68.2 65.0 57.9 106.5 75.0 76.5 79.0 63.0 80.0 93.4 107.5 107.5

note: Line No. 3 represents gravity immediately after charge.

Monday 28 February 1955



Percent Recovery (Order A1 - D3)												
Immediately After Charge:												
42.1	35.0	55.5	66.6	61.2	60.0	38.9	47.3	57.1	57.9	72.0	42.8	
24 Hours After Charge:												
52.6	60.0	88.9	85.7	94.4	95.0	61.1	73.6	76.3	84.2	84.0	71.4	

Note: Line No. 3 represents gravity immediately after charge.

two cycles the Group Two cells show a slightly greater average drop during the discharge process. At the end of the charging process during which the same number of ampere-minutes were charged as were discharged, the data indicates that both methods of charging were equally effective. The next set of readings taken 24 hours after completion of the charge shows no definite trend to indicate a superiority of either charging procedure.

7. Tuesday 1 March 1955.

During the discharge phase of the cycle for this date, the cell gravities again show a nearly equal average drop for both battery groups. Three sets of gravities were obtained following completion of the charge for this cycle. The first set taken immediately after completion of charging shows a definite advantage for the forced gassing charge of Group One cells. The data 24 hours after completion still is favorable for the method of charging Group One cells. After 48 hours from completion of the charge for this cycle, the data still indicates a better recovery in the Group One cells. It is noted that the recovery indicated is greater than 100% in some of the Group One cells. This can not be surely charged to evaporation and evolution of electrolyte since the change in electrolyte level is insufficient to account for same.

8. Thursday 3 March 1955.

It is again to be noted that the grouping of the battery cells changes as of this day's cycle. Group One now consists of cells A1, A2, A3, B1, B2, and B3. The remainder of the cells are included in Group Two.

The average drop in specific gravity is nearly equal in both battery

1220

Tuesday 1 March 1955

1210

S
P
E
C
I
F
I
C
G
R
A
V
I
T
Y

1190

1180

1170

1160

1 - Charged
2 - Discharged
3 - Recharged

GROUP ONE

GROUP TWO

1150

A2

A3

B1

B2

B3

C1

C2

C3

D1

D2

D3

BATTERY CELLS

Percent Recovery (Order A1 - D3)

Immediately After Charge:

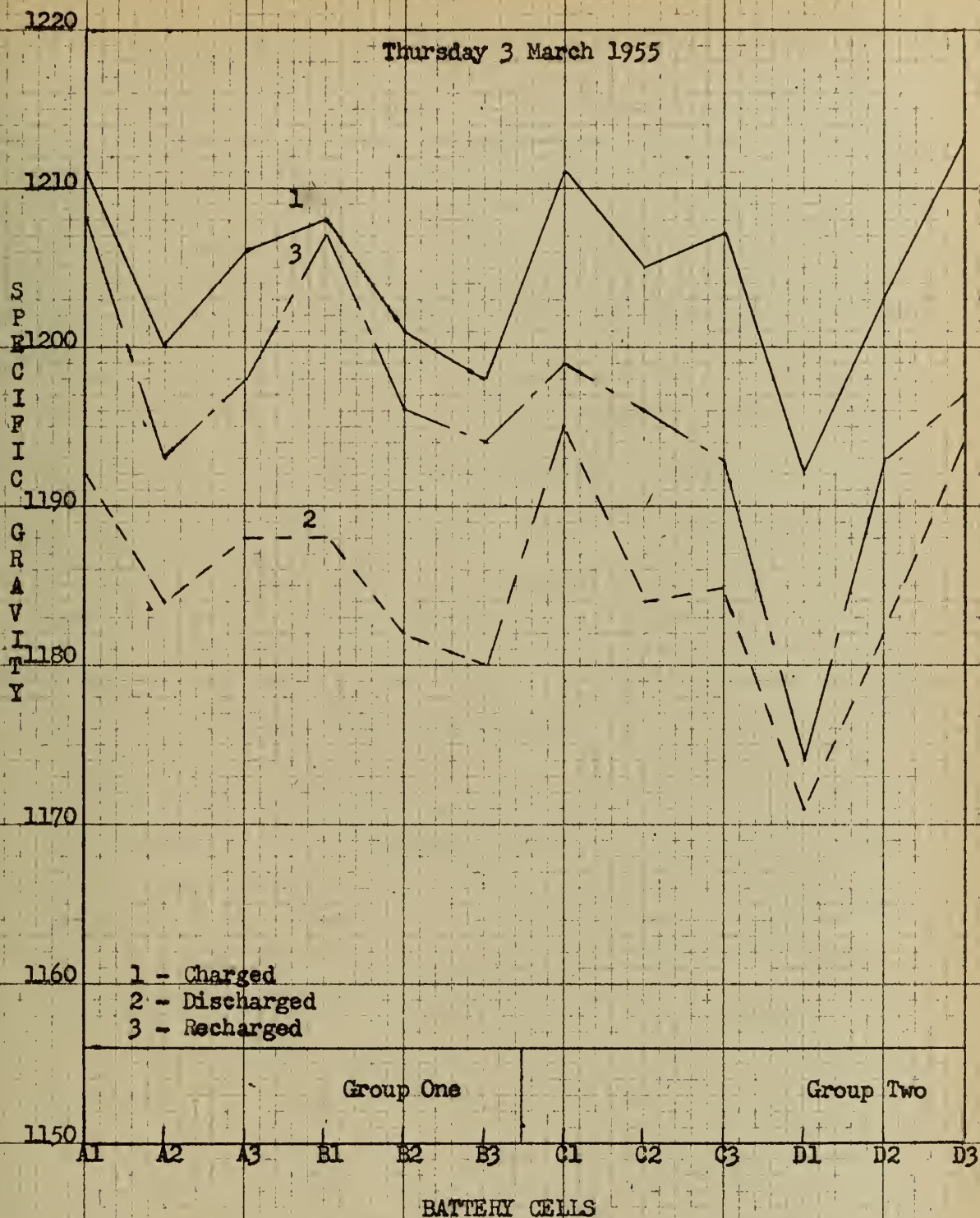
70.5 66.6 52.6 65.2 49.2 42.1 55.0 70.0 66.6 45.0 65.2 33.3

24 Hours After Charge:

100.0 86.5 78.9 60.9 65.0 57.8 75.0 80.0 90.5 55.0 61.5 42.8

Note: Line No. 3 represents gravity immediately after charge.

Thursday 3 March 1955



Percent Recovery (Order A1 - D3)

Immediately After Charge:

84.2 62.5 55.5 95.0 73.6 77.6 25.0 57.2 36.3 14.3 52.3 15.8

5 Days After Charge:

142.0 131.0 122.2 80.0 79.0 128.0 119.0 124.0 104.5 109.5 109.5 115.5

Note: Line No. 3 represents gravity immediately after charge.

groups for this discharge. A comparison of the gravities immediately upon securing the charging process indicates a greater rise in gravity in the Group One cells. After an interval of five days from completion of the charge for this cycle all cells show a considerable increase in specific gravity. The average increase is nearly the same in both groups but the Group Two cells show a uniform rise compared to the erratic changes in Group One gravities.

9. Tuesday 8 March 1955.

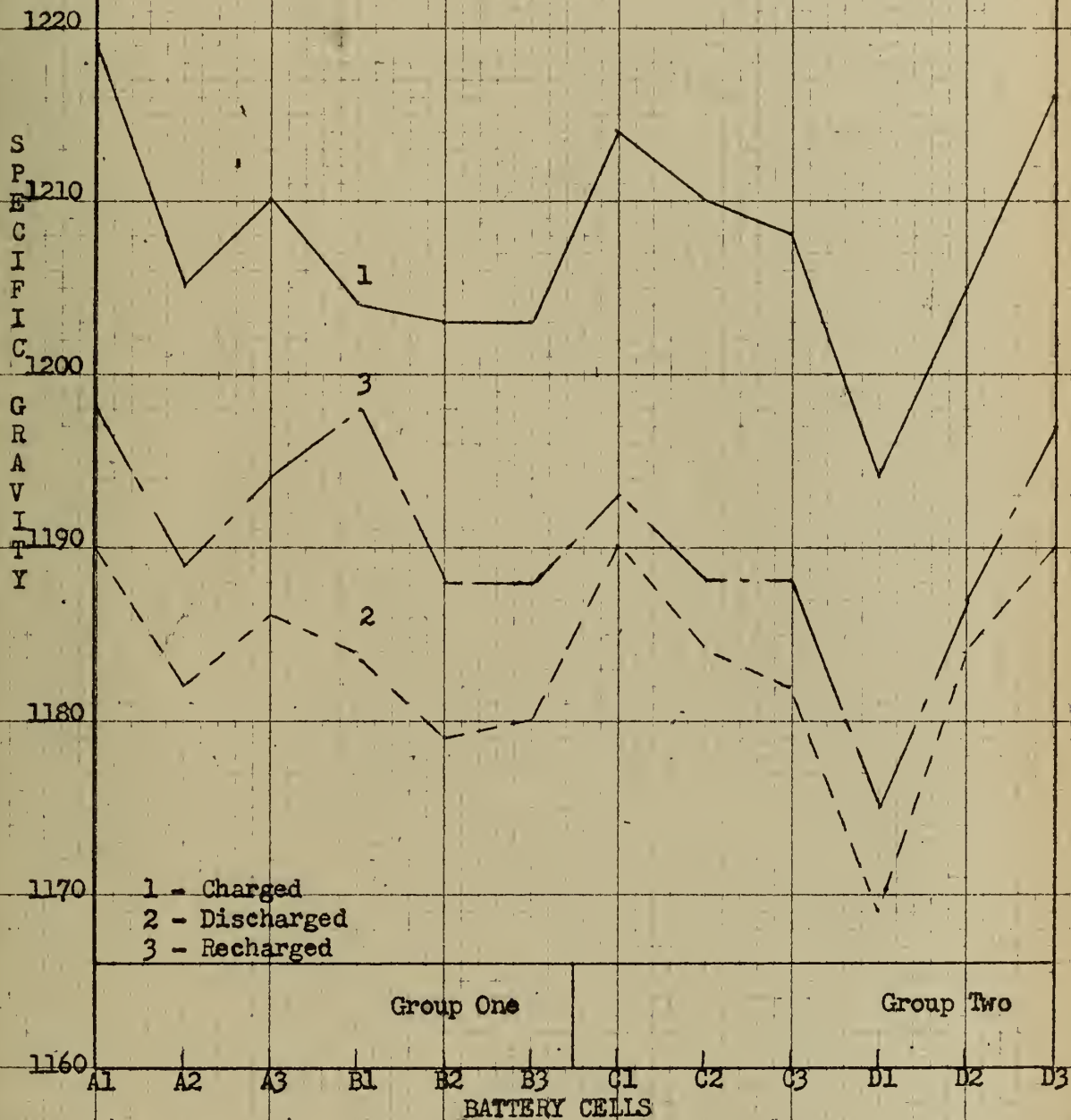
All cells dropped nearly the same number of points while discharging. At the end of the charge period the specific gravities of the Group One cell show a marked greater increase than those of Group Two. This difference in gravity levels still favors the Group One cells after a period of 24 hours with all cells on open circuit. However, the difference is less than immediately after charge.

10. Wednesday 9 March 1955.

The gravities of all cells are now twenty to twenty five points below their level for the fully charged condition as a result of the series of partial charges to date. During the discharge all cells again drop approximately the same number of points of gravity, indicating a balanced condition in regard to capacity has been maintained to date. Immediately after the charge for this cycle the measured gravities are definitely in favor of the forced gassing method of charge. Again after 48 hours on open circuit, the level of gravities is favorable to the method of charging Group One cells. It is to be noted that the cells which were transposed from Group One to Group Two on 3 March are following the manner of behavior of the cells in their new group as

1230

Tuesday 8 March 1955



Percent Recovery (Order A1 - D3)

Immediately After Charge:

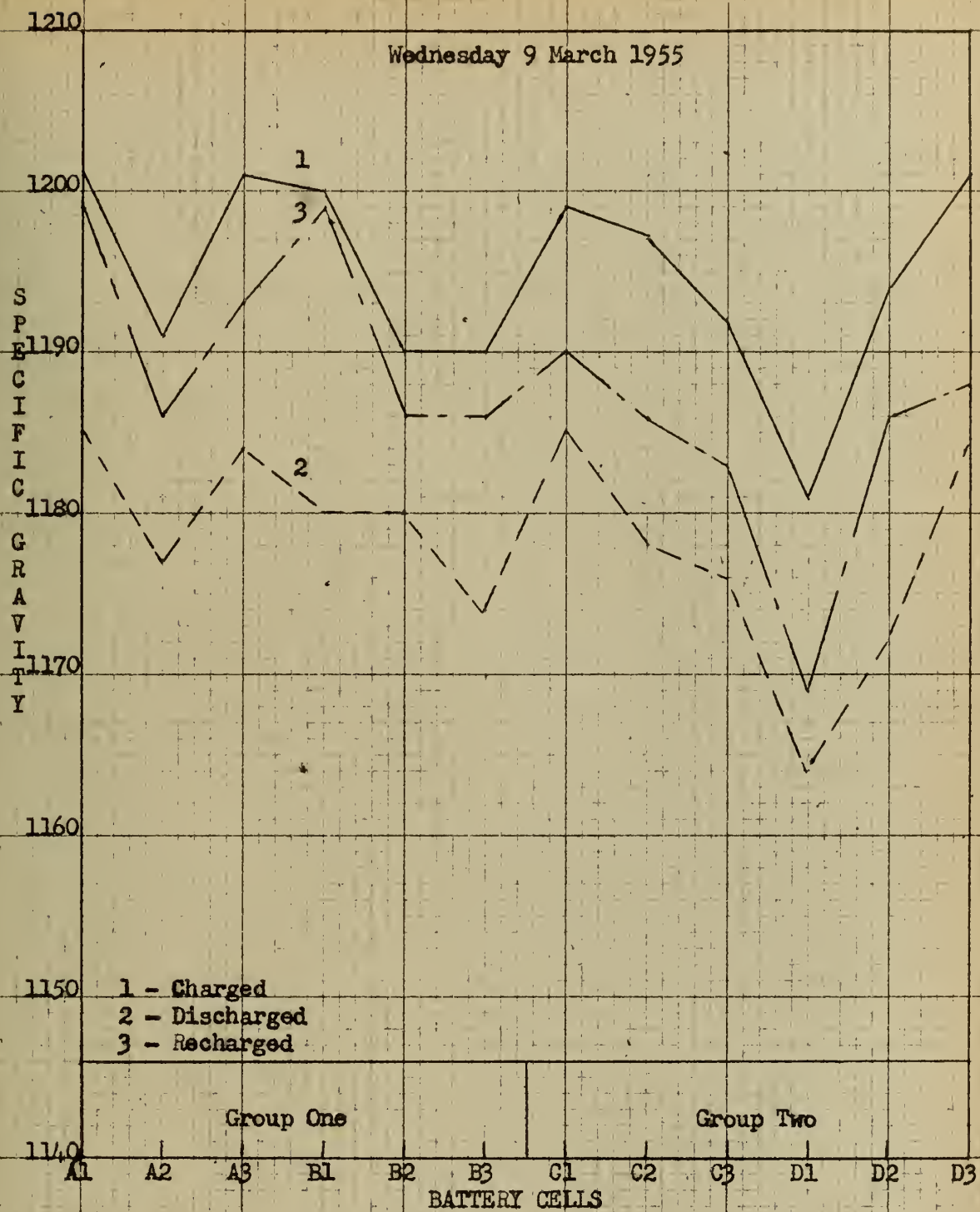
27.6 30.4 33.3 70.0 37.5 34.8 12.5 15.4 23.1 24.0 14.3 26.9

24 Hours After Charge:

37.9 39.1 62.5 80.0 45.8 43.5 37.5 50.0 38.5 48.0 47.7 42.3

Note: Line No. 3 represents gravity immediately after charge..

Wednesday 9 March 1955



Percent Recovery (Order A1 - D3)

Immediately After Charge:	87.5	64.2	52.9	95.0	60.0	75.0	35.7	42.1	43.7	17.7	63.6	23.5
48 Hours After Charge:	131.0	135.0	106.0	115.0	160.0	150.0	121.0	105.0	106.0	106.0	113.0	112.0

Note: Line No. 3 represents gravity immediately after charge.

expected.

11. Friday 11 March 1955.

As in previous cycles to date, the gravities in both groups show an nearly equal drop in all cells at the end of the discharge process.

The data at the end of the charge process shows a somewhat similar pattern as in the cycle immediately preceding. The specific gravities show the greatest recovery in the Group One cells immediately after the charge was secured, but after a period of eleven days on open circuit, the gravities in all cells have increased to the point where there is little difference in the amount of recovery since discharge.

12. Tuesday 22 March 1955.

The long interval of eleven days since the last cycle caused by extra curricula course requirements during the period between school terms has allowed all cell gravities to rise to their maximum obtainable, by natural equalization prior to this discharge. During discharge, the cells in both battery groups show nearly the same average drop. The specific gravities for Group One cells charged at a rate to produce moderate gassing during the entire charge process as per the usual procedure for this group show a definitely greater rise than the Group Two cells. It is to be noted that the Group Two cells made an unusually small recovery during the charge. The Group One cells maintain their greater rise in gravity in observations made 24 hours after the charge was completed.

13. Wednesday 23 March 1955.

The level of specific gravities is now an average of thirty points below the full charge specific gravity in all cells. During the dis-

1220

Friday 11 March 1955

1210

SPECIFIC GRAVITY

1200

1190

1180

1170

1160

- 1 - Charged
2 - Discharged
3 - Recharged

Group One

Group Two

1150

A1 A2 A3 B1 B2 B3 C1 C2 C3 D1 D2 D3

BATTERY CELLS

Percent Recovery (Order A1 - D3)

Immediately After Charge:

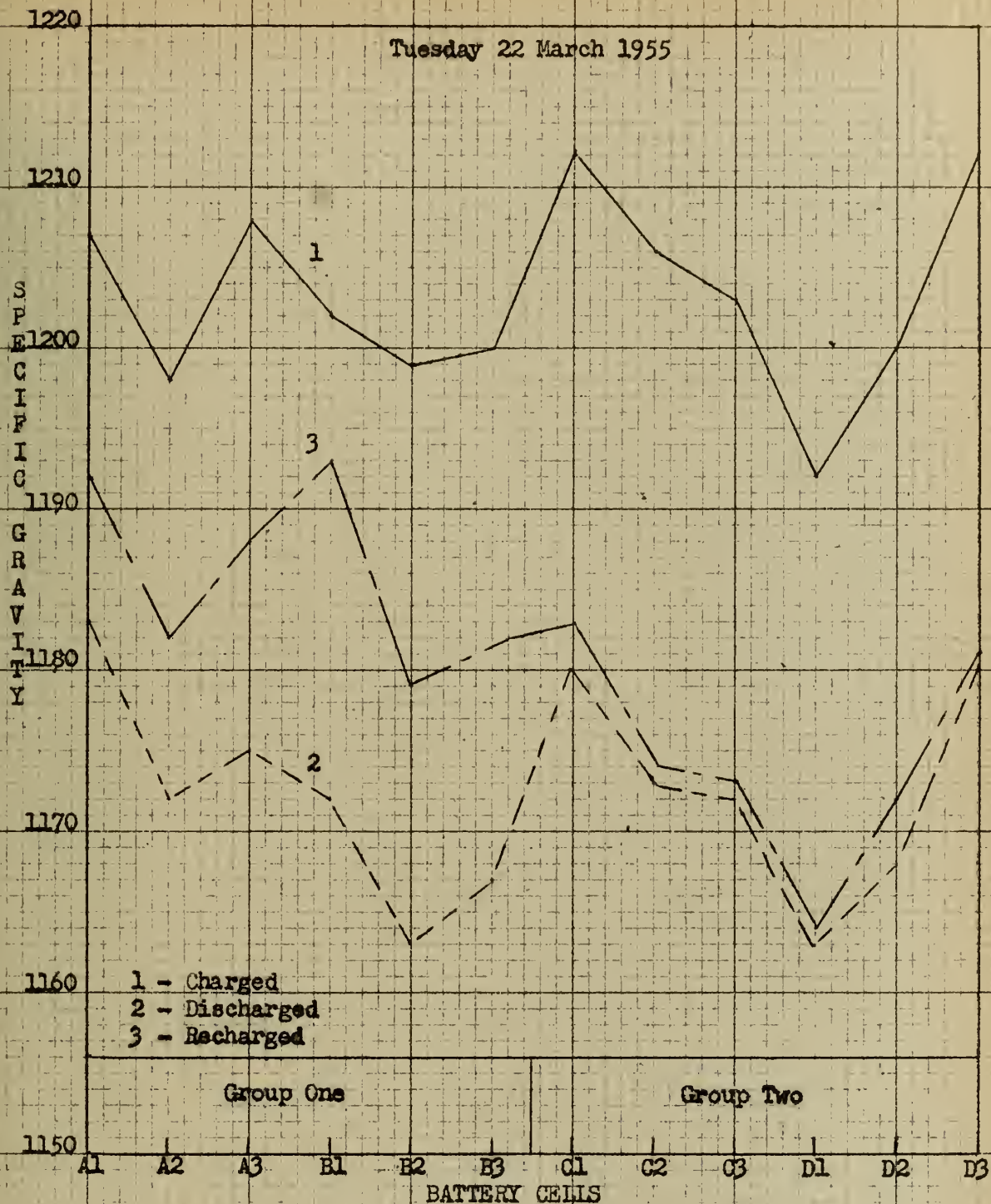
38.1 40.8 30.0 121.0 64.0 58.6 15.8 34.8 35.0 25.0 50.0 17.4

4 Days After Charge:

104.5 109.0 130.0 147.5 112.0 107.0 152.5 134.8 150.0 150.0 111.4 134.8

Note: Line No. 3 represents gravity immediately after charge..

Tuesday 22 March 1955



Percent Recovery (Order A1 - D3)												
Immediately After Charge:												
37.5	38.5	39.4	70.0	44.5	45.5	9.38	3.03	3.23	3.45	12.5	3.13	
24 Hours After Charge:												
37.5	46.2	54.5	76.7	52.8	57.5	18.7	30.3	22.6	24.1	40.6	25.0	

Note: Line No. 3 represents gravity immediately after charge.

1210

Wednesday 23 March 1955

1200

SPECIFIC GRAVITY

1190

1180

1170

1160

1150

1 - Charged
2 - Discharged
3 - Recharged

Group One

Group Two

1140

A1

A2

A3

B1

B2

B3

C1

C2

C3

D1

D2

D3

BATTERY CELLS

Percent Recovery (Order A1 - D3)

Immediately After Charge:

60.0 87.5 60.0 90.5 84.5 72.3 0.0 75.0 89.0 110.0 125.0 44.0

24 Hours After Charge:

160.0 112.5 66.6 100.0 138.5 88.9 200.0 162.5 144.4 120.0 150.0 155.5

Note: Line No. 3 represents gravity immediately after charge.

charge of this cycle, several cells in Group One are noted to have dropped considerably more than the average drop in Group Two cells. From the data taken immediately succeeding the charging portion of the cycle, it is seen that the average rise in gravity is nearly the same in both battery groups. However, the cells in Group One show a somewhat uniform rise, whereas the cells of Group Two show considerable variation. Twenty-four hours after the charge was completed, Group Two cells show a greater recovery than Group One and the extreme variations in Group Two are no longer present.

14. Thursday 24 March 1955.

The starting level of electrolyte gravities as measured before the discharge seems normal considering that all charging to date has consisted of 100% ampere-minutes discharged. As was expected, the specific gravity level is dropping a small amount with each cycle. The drop in specific gravity at the end of the discharge portion of the cycle is nearly the same in both battery groups. From the partial data recorded upon completion of the charging process, it appears that Group One cells have recovered the most in comparisons immediately after charge and 48 hours after charge. As can be seen on the data sheets, part of the pertinent data for this cycle has been lost.

15. 26 March 1955.

Considering the specific gravity prior to the discharge for this cycle, it is seen that with the exception of cell no. D3, which has been consistently lower than all others since first being placed in service, that the average level is nearly the same in both groups. This would indicate that considering the overall series of cycles to

1210

Thursday 24 March 1955

1200

SPECIFIC GRAVITY

1180

1170

1160

1150

1 - Charged
2 - Discharged
3 - Recharged

Group One

Group Two

1140

A1 A2 A3 B1 B2 B3 C1 C2 C3 D1 D2 D3

BATTERY CELLS

Percent Recovery (Order A1 - D3)

Immediately After Charge:

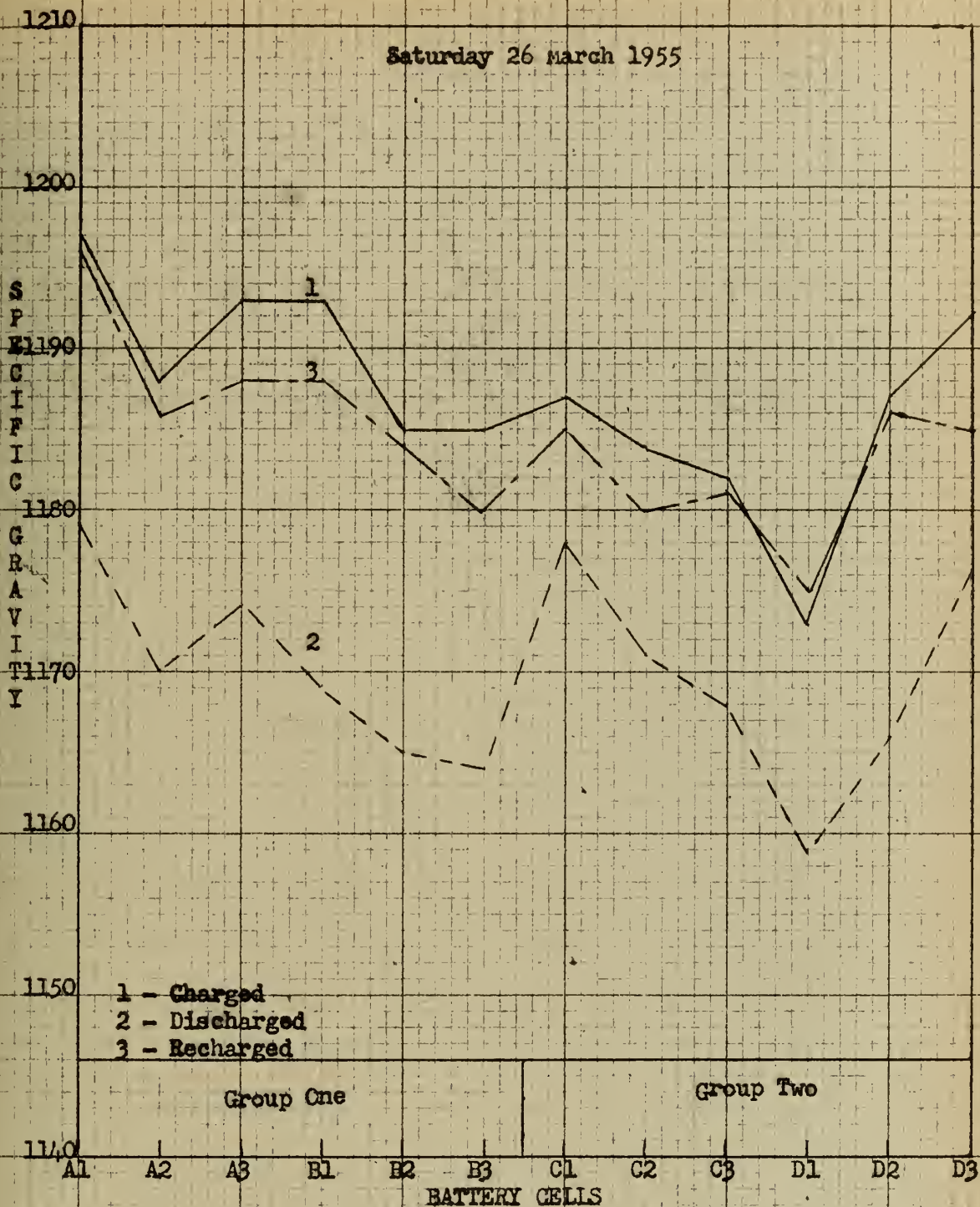
75.0 75.0 89.0 81.5 75.0 82.6 21.4 11.1 33.0

48 Hours After Charge:

95.8 115.0 127.8 92.5 91.7 104.5 85.7 77.8 94.5

Note: Line No. 3 represents gravity immediately after charge.

Saturday 26 March 1955



Percent Recovery (Order A1 - D3)												
Immediately After Charge:												
94.5	88.9	73.7	79.2	95.0	76.3	70.0	69.2	92.9	114.2	95.5	50.0	
24 Hours After Charge:												
94.5	94.5	89.5	91.7	110.0	100.0	110.0	100.0	114.3	121.5	114.3	83.4	

Note: Line No. 3 represents gravity immediately after charge.

date, neither method of charging is showing much advantage with respect to the other. The Group One cells drop slightly more in gravity this discharge than the Group Two cells. The average recovery in both groups of cells is approximately the same both immediately after charging and when comparing again 24 hours after the charge was completed.

16. Sunday 27 March 1955

The level of specific gravity of all cells prior to discharge seems normal considering the number and types of cycles utilized to date. In discharging, there is a definitely larger drop in gravity for the Group One cells compared with those of Group Two. Part of this difference seems to be in the fact that the Group Two cells dropped less than would ordinarily be expected for the number of ampere-minutes discharged.

Immediately after charge completed, the data is favorable to the Group One charging method. However, in comparing the two cell groups 48 hours after completion of the charge, the situation is reversed with the data favorable to the Group Two method.

17. Tuesday 29 March 1955.

In order to slow down the rate at which the specific gravity level has been dropping from one cycle to another, the charge for this cycle exceeds the number of ampere-minutes discharged. On a percent of recovery basis, both cell groups thus show higher values than in the past. If attention is focused to a comparison of groups, this "overcharge" does not interrupt the procedure to date. During discharge it is noted that the cells in group One dropped considerably more than those in group Two. Immediately after charge the percent recovery is nearly the same for both battery groups and again 24 hours after charge, the average

1210

Sunday 27 March 1955

1200

SPECIFIC GRAVITY

1190

1180

1170

1160

1150

1 - Charged
2 - Discharged
3 - Recharged

Group One

Group Two

1140

A1

A2

A3

B1

B2

B3

C1

C2

C3

D1

D2

D3

BATTERY CELLS

Percent Recovery (Order A1 - D3)

Immediately After Charge:

132.0 78.5 55.0 80.0 75.0 57.6 16.6 -11.1 23.1 46.1 47.4 33.3

48 Hours After Charge:

141.0 121.3 75.0 72.0 66.7 84.6 150.0 100.0 100.0 100.0 100.0 100.0

Note: Line No. 3 represents gravity immediately after charge.

1210

Thursday 29 March 1955

1200

SPECIFIC
GRAVITY

1190

1180

1170

1160

1150

- 1 - charged
- 2 - Discharged
- 3 - Recharged

Group One

Group Two

1140

A1

A2

A3

B1

B2

B3

C1

C2

C3

D1

D2

D3

BATTERY CELLS

Percent Recovery (Order A1 - D3)

Immediately After Charge:

118.1 100.0 90.0 120.0 114.0 100.0 100.0 108.0 123.0 234.0 130.0 64.6

24 Hours After Charge:

118.1 113.0 95.5 130.0 128.5 113.0 100.0 133.2 130.8 200.0 140.0 105.9

Note: Line No. 3 represents gravity immediately after charge.

recovery is nearly the same, thus indicating no advantage for either method of charge.

18. Wednesday 30 March 1955.

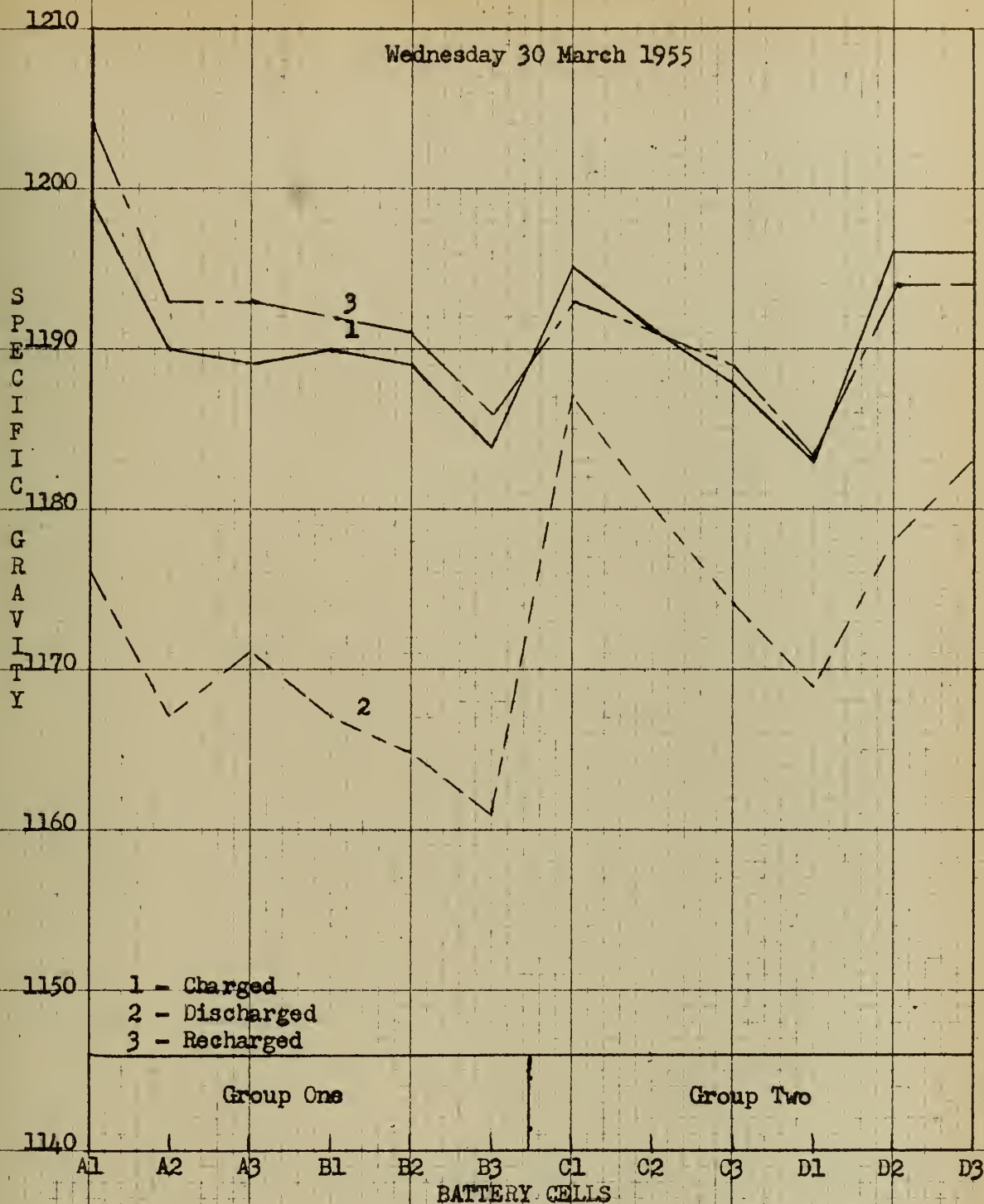
In both Group One and Group Two, the specific gravity of the electrolyte prior to discharge for this cycle has a nearly equal average value. During the discharge, the level of gravity in the Group One cells dropped much more than in Group Two. In some cases it is noted, that the drop is twice as much for Group One compared to Group Two. This is judged to be a bad effect of the charging process used for Group One cells. From an evaluation of gravity readings immediately after the charge was completed for this cycle, it appears that the method used for Group One is best under these conditions. The same evaluation applies to an analysis of readings 24 hours after charge, but to a lesser degree.

19. Thursday 31 March 1955.

Inspection of the individual cell gravities prior to the discharge, indicates that all cells are now operating in a range from 25 to 30 points below the fully charged level. The specific gravity readings taken immediately following the discharge again show a much greater drop from their pre-discharge level for the Group One cells. Contrary to the results for the preceding cycle, an evaluation of the specific gravity levels for this cycle is favorable to the charging method used for Group Two cells, both in a comparison immediately after the charging was secured and again after the considerable interval of seven days with cells on open circuit.

20. Thursday 7 April 1955.

Wednesday 30 March 1955



1 - Charged
2 - Discharged
3 - Recharged

Group One

Group Two

BATTERY CELLS

Percent recovery (Order A1 - D3)

Immediately After Charge:

122.0 113.0 122.0 65.2 185.0 108.5 75.0 100.0 107.0 100.0 88.9 84.6

24 Hours After Charge:

139.1 147.8 155.5 78.3 221.0 117.4 137.5 136.3 128.5 114.3 81.9 154.0

Note: Line No. 3 represents gravity immediately after charge.

1220

Thursday 31 March 1955

1210

SPECIFIC GRAVITY

1200

1190

1180

1170

1160

- 1 - Charged
- 2 - Discharged
- 3 - Recharged

Group One

Group Two

1150

A1

A2

A3

B1

B2

B3

C1

C2

C3

D1

D2

D3

BATTERY CELLS

Percent Recovery (Order A1 - D3)

Immediately After Charge:

93.0 82.8 107.2 86.1 82.8 113.0 110.0 100.0 121.0 100.0 124.0 110.0

7 Days After Charge:

85.7 89.7 88.9 103.3 93.2 126.0 230.0 177.0 150.0 168.5 133.0 131.5

Note: Line No. 3 represents gravity immediately after charge.

1220

Thursday 7 April 1955

1210

SPECIFIC
GRAVITY1190
1180
1170

1160

1 - Charged
2 - Discharged
3 - Recharged

Group One

Group Two

1150

A1 A2 A3 B1 B2 B3 C1 C2 C3 D1 D2 D3

BATTERY CELLS

Percent Recovery (Order A1 - D3)

Immediately After Charge:

109.5 91.5 106.5 81.5 89.3 82.2 53.8 53.5 61.5 52.0 72.4 45.8

6 Days After Charge:

104.8 100.0 146.5 89.0 82.2 85.6 96.2 100.0 107.5 92.0 89.6 116.5

Note: Line No. 3 represents gravity immediately after charge.



The level of specific gravities at the start of this cycle reflecting the results of the previous cycle now show Group Two slightly higher than Group One. Contrary to the pattern in preceding cycles, the cells in Group Two show a slightly greater drop in specific gravity in comparison with the Group One cells. However this reversal has not changed the Group Two level nearly as much below Group One as it was previously above. The level of gravities immediately after charge is again favorable to the forced gassing rate method used to charge Group One cells. Again, as in past cycles, this advantage persists but it is less pronounced after a six day interval with cells on open circuit.

21. Wednesday 13 April 1955.

The average cell in both battery groups is now 25 points below its level when fully charged. The discharge for this cycle results in a slightly greater drop in specific gravity level for Group One cells compared with those in Group Two. Although this difference is less pronounced than in some of the preceding cycles, it is judged to be a deleterious effect resulting from the Group One charging method. Again, as in many previous cycles, the specific gravities observed immediately after charge are favorable to the forced gassing charge but after a period of 24 hours during which the cells have remained on open circuit, the apparent advantage is considerably reduced.

22. Final Evaluation and Conclusions.

The method of partial charging under investigation necessarily had to be proved to be advantageous by a wide margin over ordinary charging methods in order to propose its adoption for general use. This necessity of course arises from the inherent disadvantages of the

1220

1200

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1190

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1170

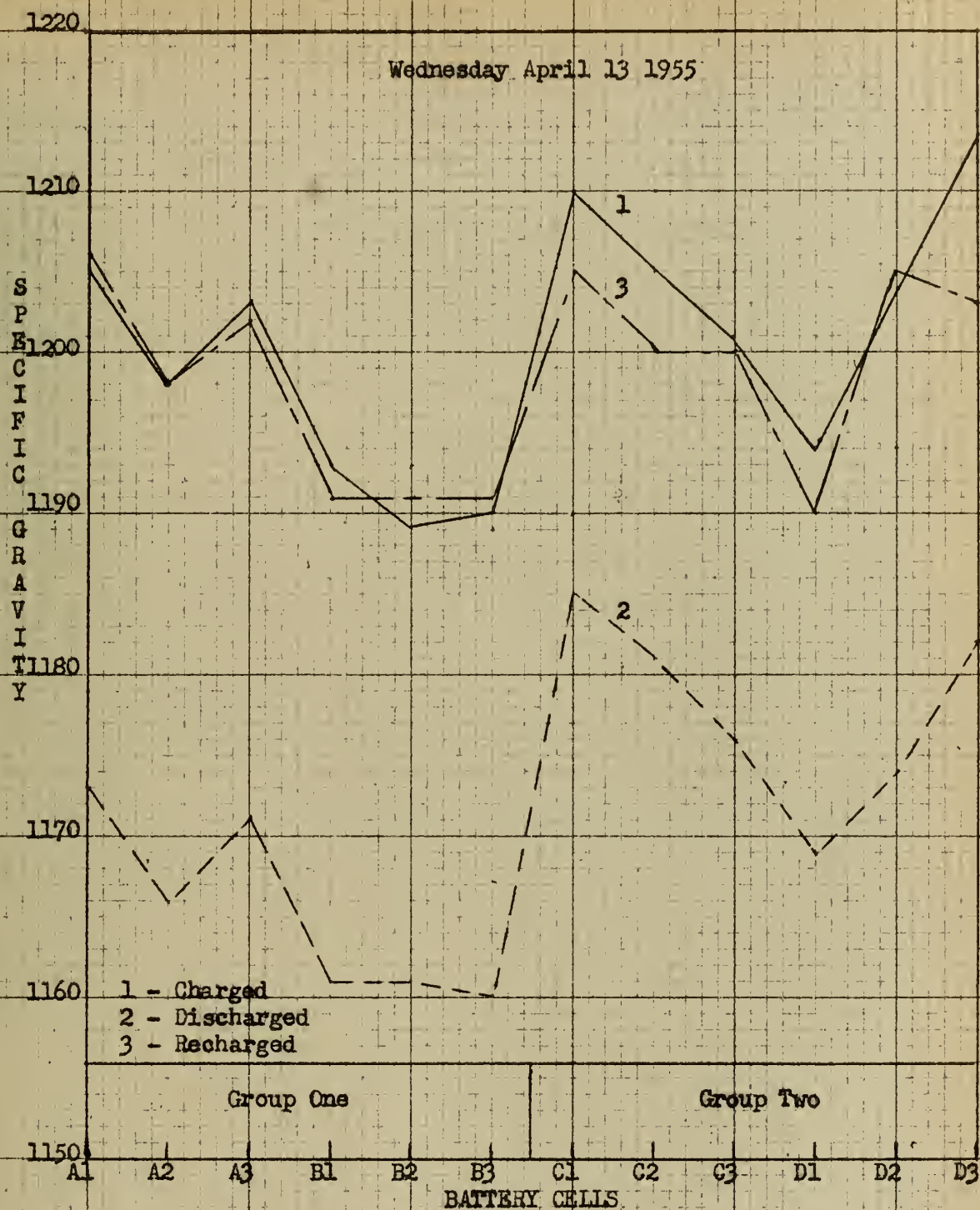
1160

1150
A

Immed
103.0
24 Ho
93.9

Note:

Wednesday April 13 1955



Percent recovery (Order A1 - D3)											
Immediately After Charge:											
103.0	100.0	97.0	93.6	107.0	103.0	80.0	79.2	96.0	84.0	103.0	67.7
24 Hours After Charge:											
93.9	96.9	100.0	103.0	125.0	113.2	92.0	91.6	96.0	108.0	106.7	80.7

Note: Line No. 3 represents gravity immediately after charge.

proposed forced gassing charging procedure, such as the additional hydrogen gas evolved, the higher rated charging equipment required, and the tendency for the higher charging rates when used repeatedly to peroxidize the positive grids. It is apparent from the detailed analysis of each cycle that the hoped for wide margin advantage did not materialize in the course of the investigation. That favorable evidence did not materialize, is strikingly notable in the comparisons made 24 or more hours after completion of charging. In the extended periods after the charge was completed, the electrolyte in Group Two cells equalized in density and composition to the point where it was the near equal of that in Group One. This of course, refutes the theory that the efficiency of charging is improved by electrolyte mixing. It does indicate, however, that with electrolyte mixing, the specific gravity is a much better measure of battery condition. For this reason alone, some mechanical mixing of electrolyte can be strongly recommended where specific gravity readings are used to precisely gauge the condition of lead-acid battery cells.

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APPENDIX I
LABORATORY TECHNIQUE

1. Cell Ventilation.

The first problem that had to be solved prior to getting the experimental work underway concerned the safe disposal of the evolved hydrogen. The accompanying picture shows part of the closed ventilation system that was developed for each cell. The cell cap for each cell was drilled and a short glass tube was inserted and cemented in place. The small normal vent holes in the cell caps were plugged. From the glass tube in the cell cap, a length of flexible rubber tubing was used to carry the evolved gases to a water flask. The main purpose of the water flask was to provide a ready means of observing the rate of gassing in each cell. This was accomplished by connecting the rubber hose from the cell cap to a glass tube extending beneath the water level in the flask. A second short glass tube inserted through the flask stopper collected the gas from above the water level, and via a second hose carried the gas to a common exhaust manifold. The exhaust manifold consisting mainly of several T sections for one-half inch pipe was in turn vented to the outside atmosphere via rubber tubing and a long glass tube. The tube extended out through an aperture in the wall normally used for an antenna lead in.

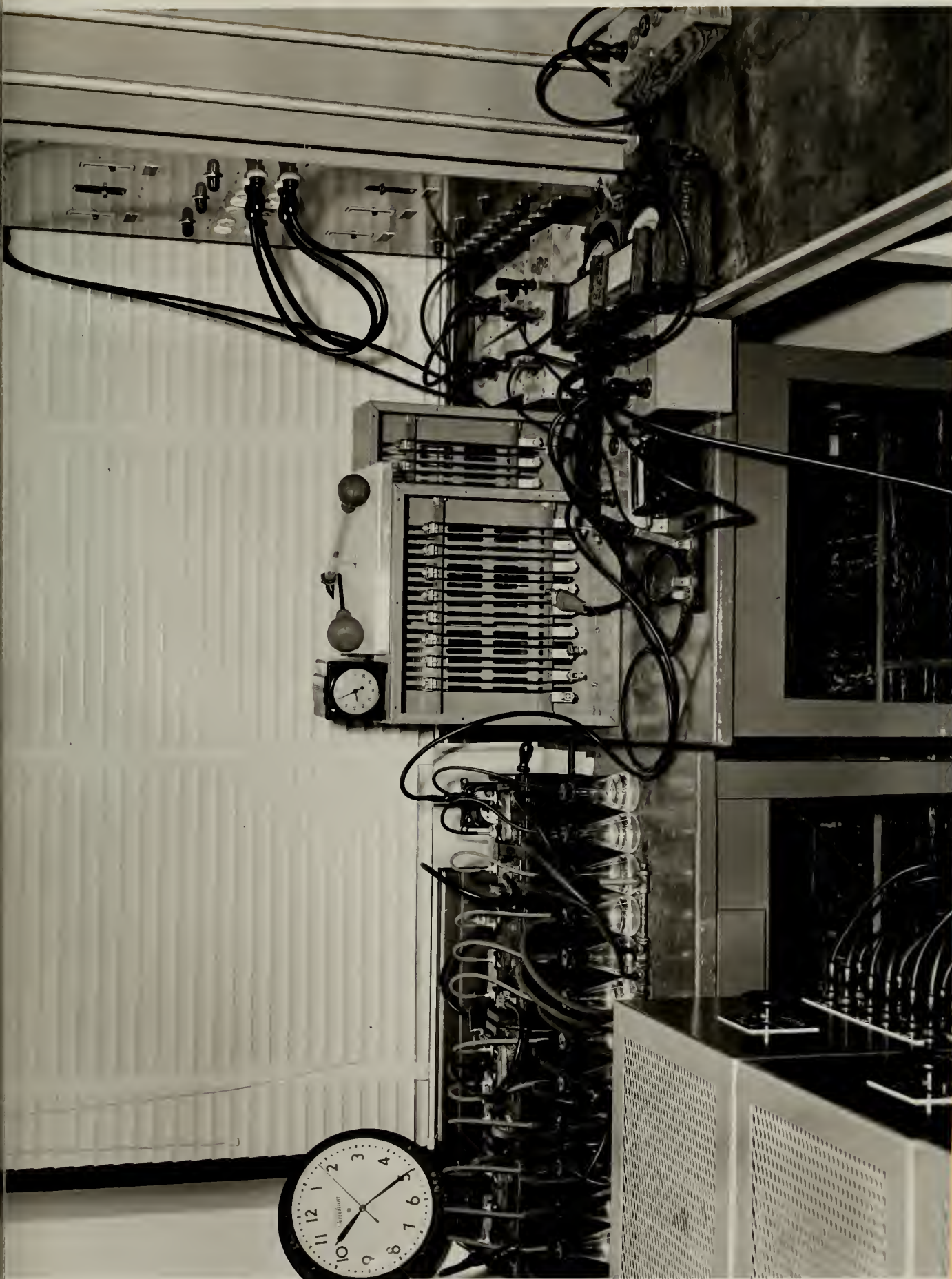
2. Discharging.

All discharging was accomplished with all cells of both groups in series. The discharges were made with the two variable resistor banks shown on the table in center of the picture as the load element. The rate of discharge was maintained constant by varying the position of

connector clamp on the strap conductors of the load bank. The length of time of discharge was accurately regulated to provide a known discharge in ampere-minutes.

3. Charging.

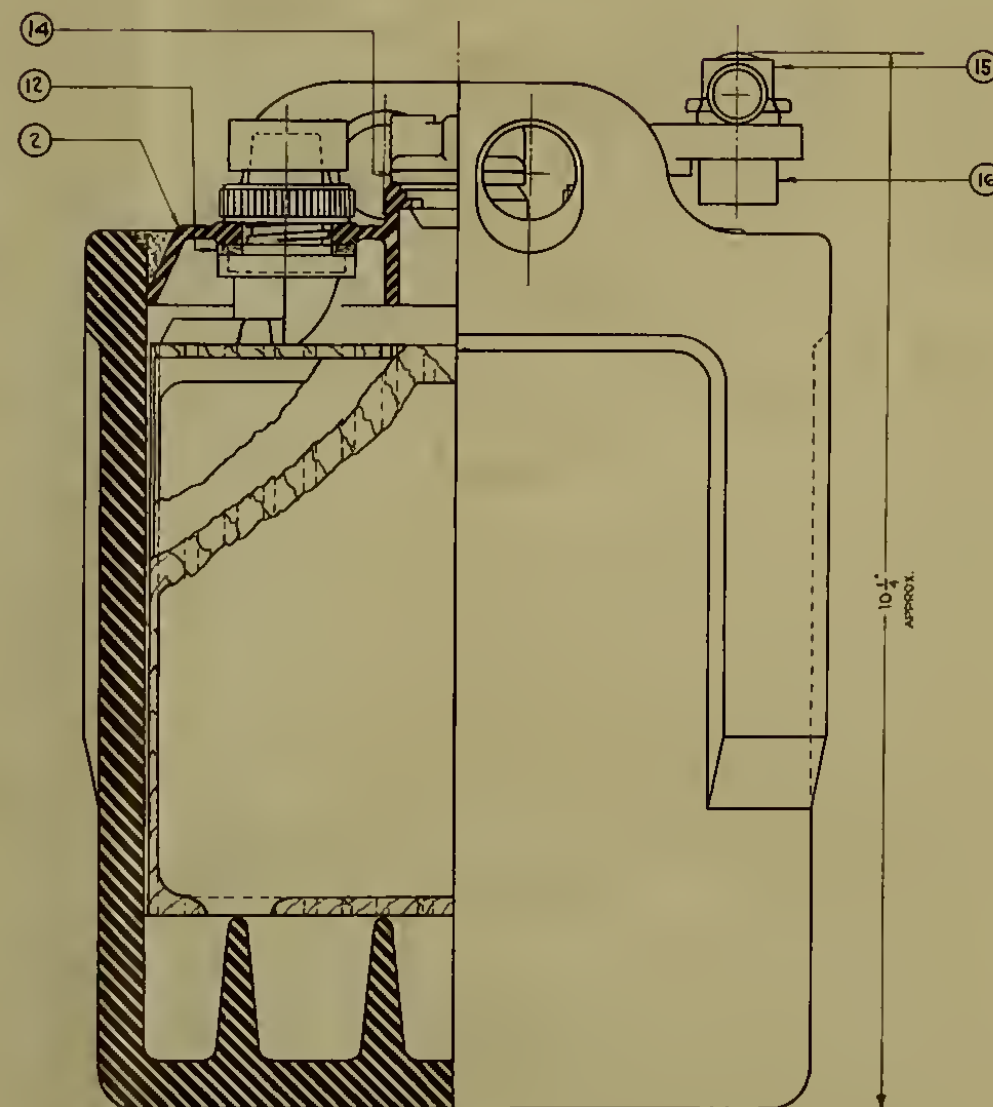
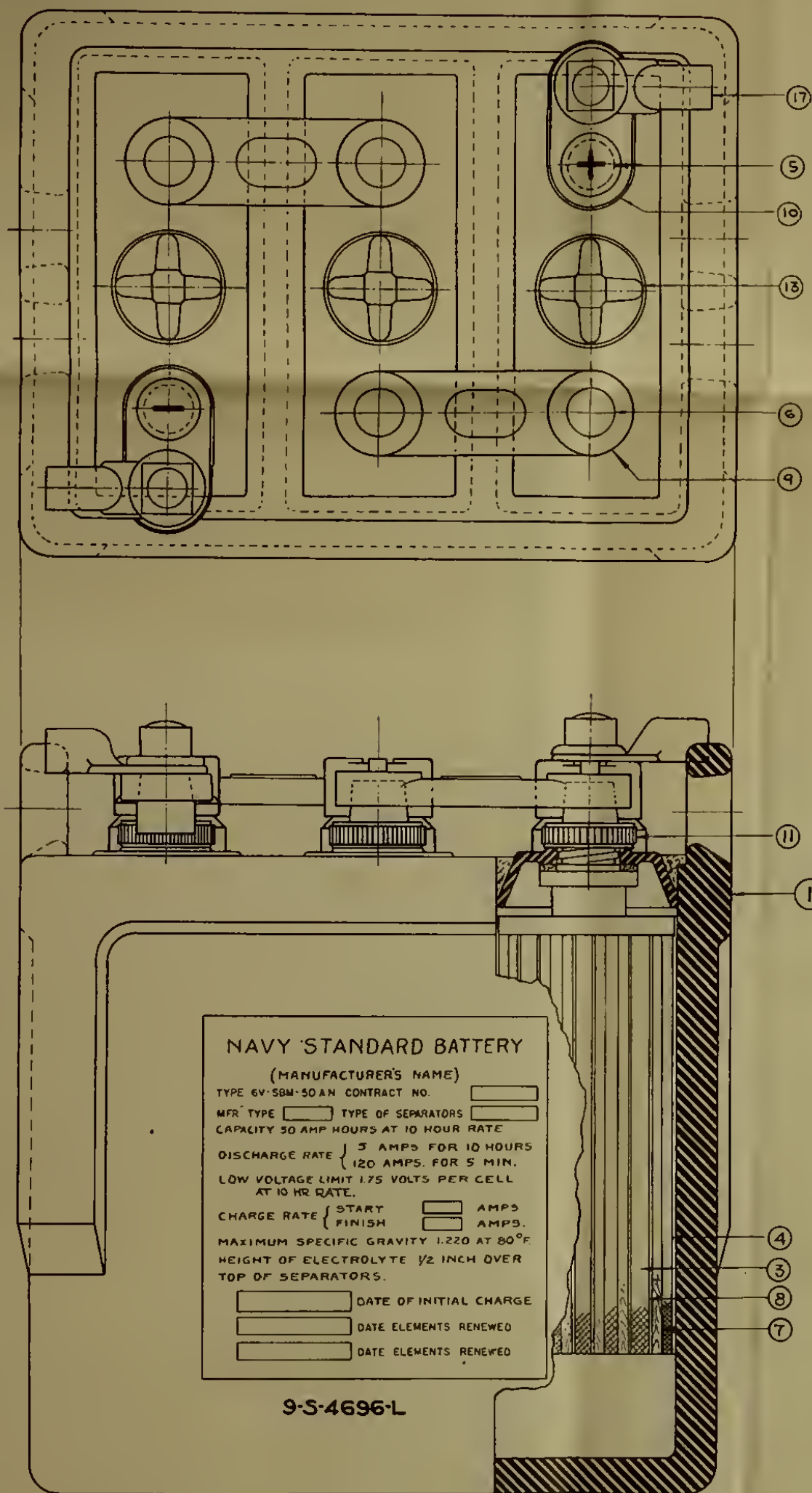
The cells were divided into two separate groups for charging purposes. Group One cells were charged at as high a rate as possible limited only by the fact that the gassing not exceed that which had previously been observed as the usual rate, near the finish of a normal charge. Group Two cells were charged at the normal slower rate which rarely produced gassing. The source of power for the Group One charge was the main D. C. generator provided for the laboratory. The charging rate was controlled using variable series resistance consisting of the three large resistor banks in the left foreground of the picture. A portable motor generator set operating in the adjoining room with rate control in the form of a field rheostat provided the charging source for Group Two cells. The rates and times were carefully controlled so that each group received an equal number of ampere-minutes per charge.



APPENDIX II

GLOSSARY

1221	Four numerals used to represent specific gravity 1.221
Reading	The direct reading of the hydrometer without correction
Temp.	The temperature of the cell electrolyte in degrees of fahrenheit
30 points	A reference to a change of specific gravity of the electrolyte equal to 0.030; similarly 20 points refers to a change of 0.020
Group One	Always refers to that group of cells being charged at a forced gassing rate
Group Two	Always refers to that group of cells charged in accordance with usual procedure
Charged	The battery condition at the start of an experimental cycle
Discharged	The battery condition at the end of the discharge phase of an experimental cycle
Recharged	The battery condition immediately following the charging phase of an experimental cycle
Cycle	The consecutive discharge of the battery a particular number of ampere-minutes, followed by a charge of the same number of ampere-minutes



LIST OF MATERIAL				
QUANTITIES FOR ONE STORAGE BATTERY				
PART NO.	NAME OF PART	PARTS PER UNIT	PARTS PER CELL	MATERIAL
1	CASE	1	—	HARD RUBBER 17-B-4
2	COVER	3	1	HARD RUBBER 17-B-4
3	POSITIVE GROUP PART 5 AND 3 PLATES	3	1	PLATES-LEAD
4	NEGATIVE GROUP PART 6 AND 4 PLATES	3	1	PLATES-LEAD
5	POSITIVE STRAP	3	1	ANTIMONY-LEAD ALLOY
6	NEGATIVE STRAP	3	1	ANTIMONY-LEAD ALLOY
7	SEPARATOR	18	6	MEMBRANOUS RUBBER
8	RETAINER	18	6	SEE NOTE 12
9	INTERCELL CONNECTOR	2	—	ANTIMONY-LEAD ALLOY
10	TERMINAL CONNECTOR	2	—	ANTIMONY-LEAD ALLOY
11	SEAL NUT	8	2	ANTIMONY-LEAD ALLOY
12	GASKET FOR SEAL NUT	6	2	SOFT RUBBER
13	VENT PLUG	3	1	ACID RESISTING MATERIAL
14	GASKET FOR VENT PLUG	3	1	SOFT RUBBER
15	BOLT	2	—	BRASS AND LEAD AND COPPER
16	NUT	2	—	BRASS AND LEAD AND COPPER
17	LUG FOR 50,000 GM CABLE	2	—	LEAD COATED

LIST OF MATERIAL				
QUANTITIES ARE FOR ONE STORAGE BATTERY				
REF. NUMBER	NAME OF PART	NUMBER WANTED	PARTS PER CELL	MATERIAL
1	CASE	1	—	HARD RUBBER
2	COVER	3	1	HARD RUBBER
3	POSITIVE GROUP PART 5 AND 3 PLATES	3	1	PLATES-LEAD
4	NEGATIVE GROUP PART 6 AND 4 PLATES	3	1	PLATES-LEAD
5	POSITIVE STRAP	3	1	ANTIMONY-LEAD ALLOY
6	NEGATIVE STRAP	3	1	ANTIMONY-LEAD ALLOY
7	SEPARATOR (WOOD)	18	6	MEMBRANOUS RUBBER
8	SEPARATOR (RUBBER)	18	6	MEMBRANOUS RUBBER
9	INTERCELL CONNECTOR	2	—	ANTIMONY-LEAD ALLOY
10	TERMINAL CONNECTOR	2	—	ANTIMONY-LEAD ALLOY
11	SEAL NUT	8	2	ANTIMONY-LEAD ALLOY
12	GASKET FOR SEAL NUT	6	2	SOFT RUBBER
13	VENT PLUG	3	1	ACID RESISTING MATERIAL
14	GASKET FOR VENT PLUG	3	1	SOFT RUBBER
15	BOLT	2	—	BRASS AND LEAD AND COPPER
16	NUT	2	—	BRASS AND LEAD AND COPPER
17	LUG FOR 50,000 GM CABLE	2	—	LEAD COATED

NOTES:

4.- TO FACILITATE MOLDING THE CASE, PC. 1, A BLANK SPACE OF THE DIMENSIONS OF THE NAMEPLATE RECESS AND 1/2" DEEP WILL BE PERMITTED ON THE OUTSIDE WALL, ON THE OPPOSITE SIDE OF THE BATTERY FROM THE NAMEPLATE.

5.- APPROXIMATE WEIGHTS
BATTERY IN BONE DRY CONDITION . . . 43-LBS.
BATTERY IN BONE DRY CONDITION, PACKED FOR SHIPMENT . . . 55-LBS.
BATTERY FILLED AND CHARGED . . . 51-LBS.
BATTERY FILLED AND CHARGED, PACKED FOR SHIPMENT . . . 62-LBS.

6.- REPLACEMENT ELEMENTS SHALL BE COMPOSED OF PARTS 2, 3, 4, 7, 8, 11, 12, 13, AND 14 ASSEMBLED.

7.- GLASS MAT RETAINERS MAY BE FURNISHED IN ADDITION TO OR IN PLACE OF PERFORATED OR SLOTTED PLASTIC RETAINERS, PART 8.

8.- STORAGE BATTERY SHALL CONFORM TO NAVY DEPARTMENT SPECIFICATIONS 17-C-4.

9.- BATTERY SEALING COMPOUND SHALL CONFORM TO NAVY DEPARTMENT SPECIFICATION 17-C-12.

10.- PC. 9-1/64" BOSS OPTIONAL. DIMENSIONS OPTIONAL EXCEPT WHEN REQUIRED FOR PARTS STOCK.

11.- PLATE THICKNESS SHOWN IS MINIMUM IF CAPACITY REQUIREMENTS OF NO SPECIFICATION 17-B-4 ARE SATISFIED A FEWER NUMBER OF PLATES HAVING GREATER THICKNESS MAY BE USED PROVIDED THE ELEMENTS MAY BE INSTALLED IN THE CASE SHOWN.

12.- MATERIAL FOR RETAINER, PC. 8 SHALL BE PLASTIC SPEC. 17-P-8, RUBBER OR GLASS FIBER.

STOCK NO.	CLASS	SYMBOL	WEIGHT
17-B-9913	6V SBM-50AH	1492	SEE NOTE 5

REVISION	DATE	DESCRIPTION	BY	TECH. DESIGN
7	11-8-49	NOTE 11 ADDED. CASE HANDLE AND DIMENSIONS CHANGED.	LLP	
6		PC. 17 WAS 50,000 GM CHGD		
5		PC. 17 WAS 50,000 GM CHGD		
4		NOTE 6, 7, 8, 9 ADDED		
3		NOTE 11 ADDED		
2		NOTE 12 ADDED		
1		NAMEPLATE CHANGED		

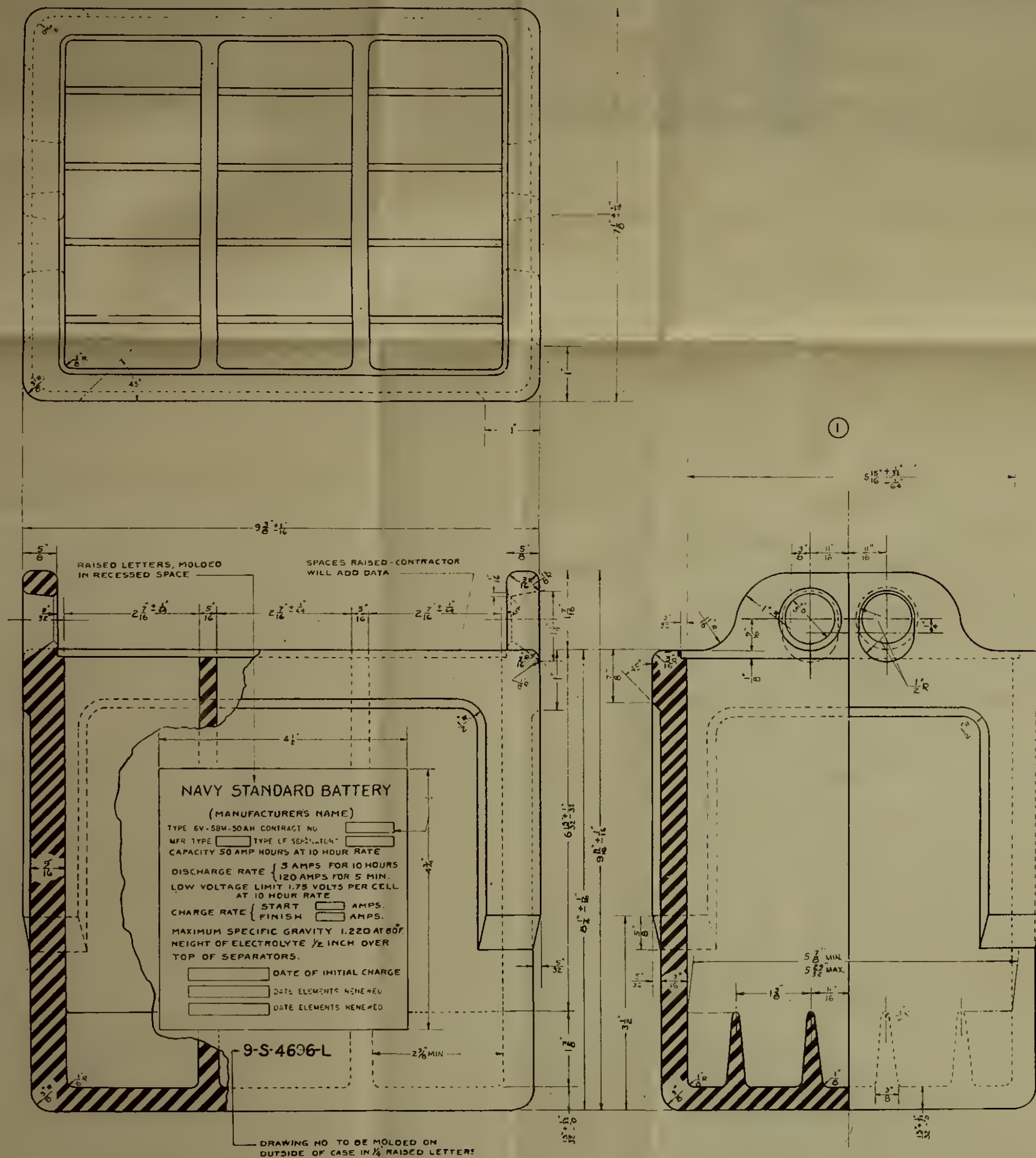
PORTABLE STORAGE BATTERY
CLASS 6V - SBM - 50AH
6 VOLT, 50 AMPERE HOUR

SCALE . . . 12 INCHES = 1 FOOT.

BUREAU OF SHIPS
NAVY DEPARTMENT,
Washington, D. C., October 25, 1933

ENGINEER-IN-CHIEF, U. S. N.
TOTAL NO. OF SHEETS 3

TOLERANCE UNLESS SPECIFIED	DRAWN BY	INDEX	GROUP	FILE NO.
DECIMAL DIMENSIONS ± .005	TRACED BY	9	S	4696
FRACTIONAL DIMENSIONS ± 1/64	INSPECTED BY			
	CHIEF DFTN			
	HEAD OF DIVISION			



CORRECT	FOR	ALT. NO.
1	6	
2	7	
3	8	
4		
5		

PORTABLE STORAGE BATTERY
CLASS 6V - SBM - 50AH
6 VOLT, 50 AMPERE HOUR

SCALE 12 INCHES = 1 FOOT.

BUREAU OF SHIPS
NAVY DEPARTMENT,
Washington, D. C., October 25, 1933

2. A. TEC
SUPERSEDED BY 9-S-4696-L
ENGINEER-IN-CHIEF, U. S. N.
SHEET NO. 2 TOTAL NO. OF SHEETS 3

DRAWN BY	CHECKED BY	INSPECTED BY	CHIEF DIVISION	HEAD OF DIVISION	INDEX	GROUP	FILE NO.
C. F. R. [Signature]	C. F. R. [Signature]	C. F. R. [Signature]	C. F. R. [Signature]	C. F. R. [Signature]	9	S	4696-L-Alt



Thesis

28485

C7568 Couture

An investigation of
forced hydrogen evolution
as a method for partial
charging of lead-acid
storage batteries.

Thesis

28485

C7568 Couture

An investigation of forced
hydrogen evolution as a method
for partial charging of lead-
acid storage batteries.

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